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AN EVALUATION OF FACTORS AFFECTING ESTABLISHMENT AND SURVIVAL OF RUSSIAN WILDRYE (ELYMUS JUNCEUS FISCH.) ON FOOTHILL RANGES IN UTAH

by

Dale Lynn Drawe

A dissertation submitted in partial fulfillment
of the requirements for the degree

of

DOCTOR OF PHILOSOPHY

in

Range Ecology

Approved:

Major Professor	Committee Member
Committee Member	Committee Member
Committee Member	Dean of Graduate Studies

UTAH STATE UNIVERSITY
Logan, Utah
1970

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Dale Lynn Drawe

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ABSTRACT

An Evaluation of Factors Affecting Establishment and Survival of Russian Wildrye (*Elymus Junceus* Fisch.) on Foothill Ranges in Utah

by

Dale Lynn Drawe, Doctor of Philosophy

Utah State University, 1970

Major Professor: Dr. Jack F. Hooper
Department: Range Science

Several factors affecting establishment and survival of Russian wildrye were studied in the greenhouse and in the field.

Greenhouse studies conducted at Utah State University examined (1) the effects of competition on vigor and production of Russian wildrye, (2) moisture use by Russian wildrye and four weeds, and (3) effects of moisture level on emergence and seedling vigor.

During 1967 and 1969 at Tintic Valley field experiments were initiated to study effects on germination and seedling establishment of (1) seasons, (2) methods, and (3) intensities of seeding Russian wildrye. In 1968 and 1969 studies were made of phenology and root growth of Russian wildrye, crested wheatgrass (*Agropyron cristatum*

(L.) Gaertn.) and four weeds, halogeton (Halogeton glomeratus (Bieb.) C. A. Meyer), cheatgrass (Bromus tectorum L.), Russian thistle (Salsola kali L.), and peppergrass (Lepidium perfoliatum L.), near Green Canyon in Cache Valley. At this same location in 1968, a study was conducted of field competition between Russian wildrye and the weeds. From 1964 through 1969 in Curlew Valley a field study was conducted of effects of seasons and intensities of clipping on establishment and survival of Russian wildrye and crested wheatgrass at two stand densities.

Results showed that weed competition reduced vigor and production of Russian wildrye seedlings. Cheatgrass and Russian thistle competed most severely with Russian wildrye. Competition from halogeton and peppergrass also significantly reduced vigor of Russian wildrye. Peppergrass was the weakest competitor of the four.

Russian wildrye, crested wheatgrass, and peppergrass were the most elaborate moisture users, making them relatively poor competitors. Russian thistle had the most extensive root system, and therefore would be a severe competitor. Cheatgrass and peppergrass were early-maturing species, and Russian thistle and halogeton were late-maturing species. Greatest competition came from a combination of either early-maturing species with either late-maturing species.

Optimum planting depth for Russian wildrye was 1/4 inch. The best stand was obtained by drilling twelve pounds of seed per acre in the fall. There was no advantage of the Vinall seed over commercial seed. Failures of the Tintic Valley seedings during two consecutive years were attributed to low precipitation, variations in temperature and moisture, and lowered germination due to fungus infection of seed in the soil.

Russian wildrye out-performed crested wheatgrass under all seasons and intensities of clipping at both thick and thin stand densities. Highest production and most vigorous plants came from thin stand densities of Russian wildrye and crested wheatgrass. Greatest herbage production with least reduction in plant vigor came from Russian wildrye clipped moderately in early or mid season.

(117 pages)

INTRODUCTION

Russian wildrye (*Elymus junceus* Fisch.) is a long-lived perennial bunchgrass introduced to this continent from Siberia by the University of Saskatchewan in 1926 (Lawrence and Heinrichs, 1966). It is now widely distributed throughout the Northern Great Plains and Intermountain area (Figure 1).

The species does well in the Northern Great Plains, but even though it is recommended for foothill ranges in the Intermountain area (Plummer, et al, 1955), there are problems with establishment of Russian wildrye in the Intermountain area. This study was an attempt to fill in some of the gaps in the knowledge about establishment and survival of Russian wildrye on foothill ranges in Utah.

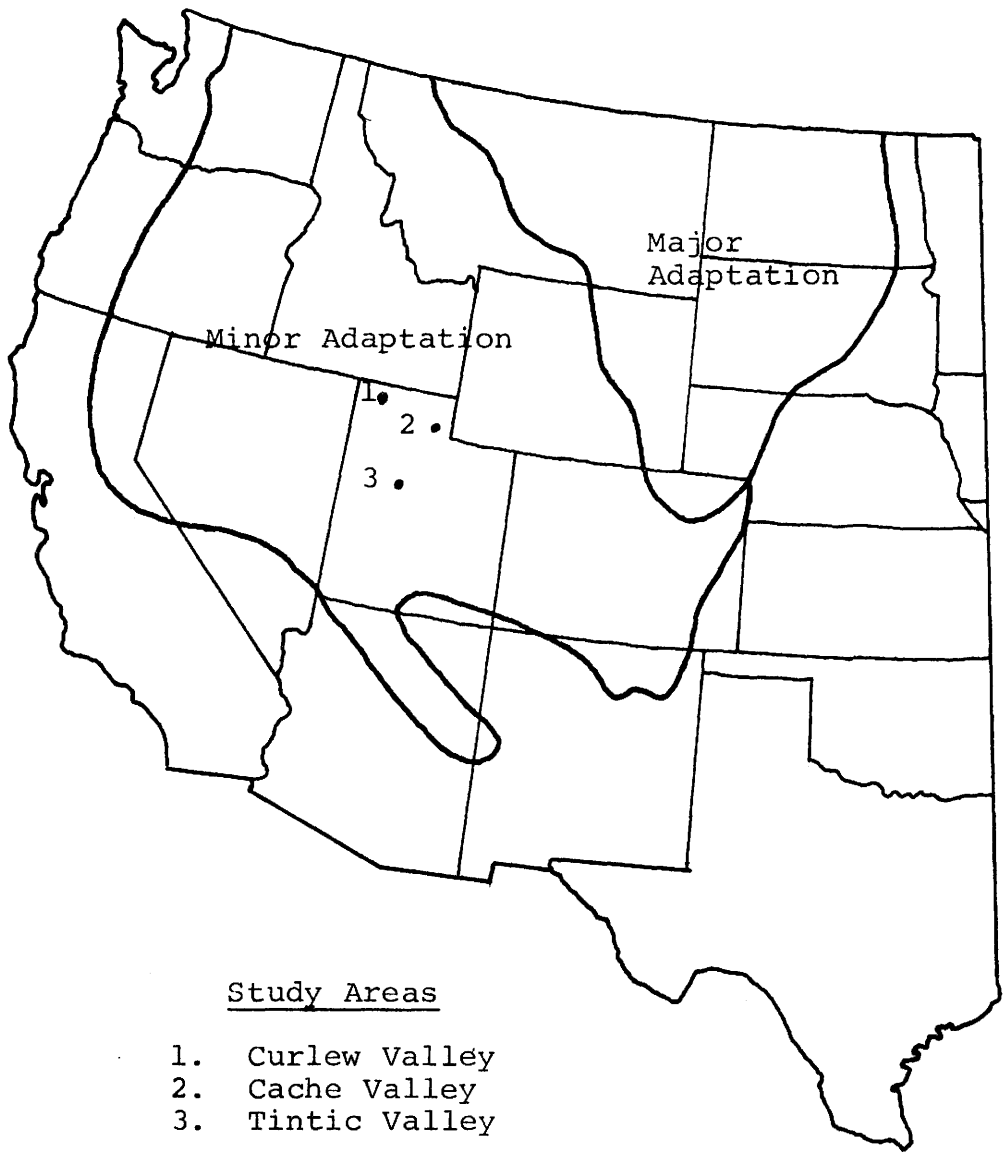

Figure 1. Area of adaptation of Russian wildrye in the United States (Rogler and Schaaf 1963), and location of study areas.

LITERATURE REVIEW

The fact that Russian wildrye is difficult to establish has been pointed out by Lawrence and Heinrichs (1966) and by Cook (1966). Because Russian wildrye seedlings develop slowly, Canadian workers recommend control of weeds by either cultivation or herbicides before seeding. Cook (1966) observed that seedlings of Russian wildrye were frail and subject to high mortality. The first year following planting, seedlings were sparse, averaging only 1.3 per square foot. There were 0.5 plants per square foot after two growing seasons.

The literature indicates Russian wildrye has been studied extensively in the Northern Great Plains and very little in the Intermountain area. The introduced wheatgrasses have been studied by the Utah State University Department of Range Science (Cook, 1958; Cook and Lewis, 1963; Cook, 1965; Cook, 1966), while only limited work has been done on Russian wildrye.

Greenhouse Studies

Competition

One of the first approaches that logically came to mind was to study the effects of other species present in the Intermountain area on the seedling phase of Russian wildrye. The importance of the seedling phase is pointed out in many of the literature sources.

Two types of competition must be recognized, interspecific and intraspecific. Both types can and should have an effect on establishment of Russian wildrye. In the interspecific type, competition is greatest for one or a few factors, such as light or moisture. This is the type Clements and Shelford (1939) consider as the driving force behind succession. Interspecific competition may tend to intensify intraspecific competition. All growth requirements are critical in intraspecific competition because of the greater similarity in requirements of all plants. In intraspecific competition, increasing the number of plants beyond the optimum reduces yield (Clements and Shelford, 1939).

Research on interspecific competition with Russian wildrye is limited. Lawrence (1967) reported that wheat sown at various spacings in rows parallel or at right angles to rows of Russian wildrye significantly reduced seed yields the first two years, as well as reducing seedling vigor. Reductions in seed yields increased with increasing density of wheat.

Undesirable species and competition. Undesirable species spread because they are well adapted to a variety of habitats. Because they make quite an impact on the economy of an area, these are the species that are studied and reported in the literature. Prime examples are cheatgrass

(Harris, 1965), halogeton (Cook, 1965), and Russian thistle.

Evans (1961) grew 18 crested wheatgrass plants with 16, 64, and 256 cheatgrass plants. At 64 and 256 plants per pot, cheatgrass severely reduced root and shoot growth of crested wheatgrass. Hull (1963a) found that shoots and roots of cheatgrass were more ramified than those of wheatgrasses. Cheatgrass competition caused considerable reduction in root and top growth of wheatgrasses. Klemmedson and Smith (1964) found that cheatgrass deterred seedling establishment of *Agropyron desertorum* and *A. smithii* and was a severe competitor under adequate moisture conditions.

Evans (1961) and Hull (1963a) have suggested that cheatgrass is more efficient in extracting soil moisture than are wheatgrasses. Hunt (1962) found that Russian wildrye produced less forage and used more water to produce a gram of dry matter than did intermediate wheatgrass.

Desirable species and competition. Desirable species are usually selected for traits such as forage production, palatability, and soil-holding ability. Adaptability to the area into which they are introduced may be a secondary consideration.

When a desirable species is introduced, several factors other than its adaptability to the general climate of the area will affect its success or failure.

Competitive ability of the desirable plant with other species present should be known. Park's (1948) work with flour beetles reminds us that the reaction of desirable species to competition with other species can be determined only by study of desirable species and potential competitors under controlled or carefully measured conditions.

Adaptability of introduced plants to the distribution of precipitation should be considered. Though the total amount of precipitation may be the same in the plant's native area and the new area, the distribution of rainfall in the new area may not allow the plant to survive. For example, Russian wildrye may establish well in the prairie where there are spring and summer rains, but in the Intermountain area this plant may be difficult to establish, due to the lack of summer rainfall.

Timing of planting should be correlated with proper temperature and moisture conditions for subsequent germination and establishment. Harper, Landragin, and Ludwig (1955) found that the number of maize seedlings emerging was different at different planting times (weekly intervals in spring, summer, and fall). There was an optimum date, before and after which there was less emergence.

Root systems and competition. It is well known that underground plant parts play as important a part in plant establishment as the above-ground parts. Therefore, a study of the root systems of Russian wildrye and several important weeds was conducted. Rapid germination and establishment of primary root systems are prerequisites to successful establishment (Weaver, 1930). Production of tillers is successful only when the secondary root system penetrates moist soil. Plants with poorly established roots and little food reserve are less resistant to winter kill. Plummer (1943) found that total root development prior to summer drought appeared to be associated directly with initial success or failure of grass seedlings.

When roots of different species are in the same horizons, competition is often severe for limited supplies of moisture, nitrates, and other resources. One reason for the success of crested wheatgrass, smooth bromegrass, and other species used in seeding ranges, is the rapid development of roots after germination (Hanson and Churchill, 1961).

Species with a faster-growing, more extensive root system could have a competitive advantage for nutrient uptake. Harper and Clatworthy (1963) have found that species with larger seed food reserves allowed seedlings to emerge from deeper planting, gave them larger photosynthetic area, and increased actual growth rates.

Plants compete for light, water, nutrients, oxygen, and carbon dioxide (Black, 1958a, 1960; Harper, 1964). Water is normally first in importance in natural communities, light second, and nutrients last. Competition is most decisive during the development of the seedling and at the time of reproduction (Weaver and Clements, 1938). Therefore, in the present study water requirements of Russian wildrye and four important weeds were determined.

Interactions with parasite populations. Interactions with predator or parasite populations may have an important influence on the competitive ability of seedlings. Harper (1955) suggested that temperature and soil moisture interact in selecting out and favoring activity of specific pathogens in the soil. He verified that maize seedling mortality was controlled by frost and pathogens (Harper, 1956). Temperatures of -10^{o} C and -5^{o} C were lethal, and pathogenic activity was at a peak at 5^{o} C.

Krietlow and Bleak (1964) found that a soil-borne fungus (*Podosporiella verticillata*) attacks range grasses and cereals in Utah, and reduces seedling emergence and vigor. Highest infection occurred in sagebrush sites. Appreciable infection could be found within two months after planting. Bleak (1966) found that in seedings of crested wheatgrass, infection potential was higher when the wheatgrass was planted into a cheatgrass stand. Therefore, since similar conditions existed in the Russian wildrye seedings made at Eureka, the possibility of fungus infection affecting germination was investigated.

Germination requirements

One explanation of the difficulty in establishing Russian wildrye on foothill ranges is that the germination requirements are not met. Therefore, investigations into germination requirements were conducted.

Potter (1951) compared the seedling characteristics of Russian wildrye and crested wheatgrass. Best germination for both species was obtained by a 6^{o} C chill followed by a constant temperature of 20^{o} C, or alternation of 20^{o} to 30^{o} C without a chill. Crested wheatgrass germinated and grew better at a slightly lower temperature than Russian wildrye. Russian wildrye imbibed water more slowly up to 48 hours, but the number of seeds germinated was twice that of crested wheatgrass. Seedlings of Russian wildrye grew more slowly and were less susceptible to frost in the first eight weeks of growth than crested wheatgrass. With favorable moisture, Russian wildrye produced more roots but less foliage than crested wheatgrass. Under drought conditions, some Russian wildrye recovered when watered after 1, 3, 5, and 10 days at permanent wilt; no crested wheatgrass recovered after more than one day at permanent wilt.

McGinnies (1960) studied the effects of moisture stress and temperature on germination of six range grasses, including Russian wildrye. Under high moisture stress all species germinated better at 20^{o} C than at 10^{o} or 30^{o} C. Russian wildrye appeared more affected by differences in temperature and moisture stress than other species. Germination fell off more rapidly when temperatures were changed or moisture stress was increased. He attributed the difficulty of establishment to this latter finding.

Plummer (1943) studied germination and early seedling development in twelve range grasses and found the best planting depth to be 1/4 inch. Hull (1964) found optimum depth of planting of cheatgrass and three wheatgrasses to be 1/2 inch for all species. He concluded that competition with cheatgrass could not be avoided by varying planting depth of wheatgrasses. This same conclusion could be drawn for Russian wildrye.

Field Studies

A limited amount of work has been done on seeding Russian wildrye in the Intermountain area. Since the native ranges of Russian wildrye and crested wheatgrass largely overlap, some information applicable to crested wheatgrass in the Intermountain area may also apply to Russian wildrye.

Hull and Holmgren (1964) have recommended that Russian wildrye be seeded on sagebrush mountain brush and juniper sites in the Intermountain area. It was useful on soils too alkaline for fairway or crested wheatgrass and too dry for tall wheatgrass.

Hull (1963b) made experimental seedings of fourteen species of grasses on eighteen areas in the salt-desert shrub region of western Wyoming. He found that Russian wildrye was the best of the fourteen species. All plants died in unprepared seedbeds. Most stands were poor in prepared seedbeds. Crested wheatgrass was slightly inferior to Russian wildrye, with some stands of Russian wildrye rating good. Other species either failed or were reduced to very poor stands.

Cook (1966) made extensive studies from 1956 to 1964 using wheatgrasses and Russian wildrye to develop foothill ranges in central Utah. Russian wildrye was not a heavy forage producer on good sites compared to crested wheatgrass. Hull and Holmgren (1964) found the same thing in Idaho. Cook (1966) found that young seedlings of Russian wildrye were frail and subject to high mortality.

Cook, Stoddart, and Sims (1967) reported the effects of season, spacing, and intensity of seeding on development of foothill range grass stands. Spring planting produced more seedlings than fall planting, but these seedlings had a higher mortality during the first two summers following seeding. A drill-row spacing of seven inches resulted in more seedlings than a fourteen-inch spacing with the same quantity of seed per acre. However, herbage yield was about the same after the plants became established.

In Wyoming, an attempt was made to interseed Russian wildrye into deteriorated native rangeland (Rauzi, Lang, and Becker, 1963 and 1965). Russian wildrye was planted at the rate of eight pounds per acre with a Wyoming range seeder at row spacings of 6, 12, 18, and 24 inches. Treble superphosphate was applied to all treatments. The study was repeated three years in succession. Native species (buffalograss and western wheatgrass) invaded the seeding and Russian wildrye died competing for water during a severe drought. They concluded not to recommend Russian wildrye for interseeding in native shortgrass ranges.

In the northern Great Plains, much interest has been shown in growing Russian wildrye for both forage and seed production (Clary, 1965; Conrad, 1946; Dotzenko and Stegmeier, 1959; and Lawrence and Ashford, 1964). Schaaf (1961) studied the effect of planting date on seed production in Russian wildrye. He found that spring-planted Russian wildrye does not produce seed until the next year. Fall plantings do not produce seed until the second growing season after establishment. Fall planting was preferable to spring planting for ease of establishment.

Studies were conducted in Canada to determine the effect of row spacing, fertilizer treatment, association with alfalfa, and early spring burning on seed production in Russian wildrye (Stelfox, Heinrichs, and Knowles, 1954). Row spacing was the most important factor affecting seed yield. Optimum spacing varied from two to four feet, depending on moisture conditions and age of the stand. Seed production increased with increasing rate of fertilization with ammonium phosphate. Alfalfa planted in the grass stand reduced seed yield slightly. Early spring burning increased seed yield in some instances and had no effect in others.

Increased rate of nitrogen fertilization and increased width of row spacing generally increase seed and forage production in Russian wildrye (Lorenz and Rogler, 1959;

Lorenz and Rogler, 1964; and Rogler and Lorenz, 1964). Greater root weight per acre occurred under rows six inches apart, however, than under rows 18 to 36 inches apart. Volume of roots increased with increasing fertilization up to 200 pounds per acre, followed by a decrease at the 400-pound per acre rate.

Effect of clipping frequency on productivity and root development of Russian wildrye has been studied both in the greenhouse (Thaine and Heinrichs, 1951) and in the field (Thaine, 1954). Increased numbers of clippings reduced yield in the greenhouse, but in the field three to five clippings per growing season produced greater yield than one to two clippings. Root yield and root reserves were decreased with increased frequency of clipping.

DESCRIPTION OF EXPERIMENTAL AREAS

Tintic Valley

The Tintic Valley location is nine miles south of Eureka, Juab County, Utah. It is situated on gently rolling ground near the steeper slopes of the foothills. The elevation is 6,000 feet.

The soil is a Tintic silt loam, which is light brown, weakly calcareous, and somewhat structureless, breaking into single grain particles (Cook, 1958).

Native vegetation consists of big sagebrush (*Artemisia tridentata* Nutt.), with a sparse undercover of bluebunch wheatgrass (*Agropyron spicatum* (Pursh) Scribn. and Smith), western wheatgrass (*A. smithii* Rydb.), Indian ricegrass (*Oryzopsis hymenoides* (Roem. and Schult.) Ricker), squirreltail (*Sitanion hystrix* (Nutt.) J. G. Smith), cheatgrass and little rabbitbrush (*Chrysothamnus viscidiflorus* (Hook.) Nutt.). Moderately dense stands of juniper (*Juniperus osteosperma* (Torr.) Little) are interspersed with the sagebrush. A few small, sparse stands of bitterbrush (*Pursia tridentata* (Pursh) DC) occur on rocky hilltops.

Precipitation is low, erratic during summer (Table 1), and coupled with a high evaporation rate which reduces its effectiveness. Mean annual precipitation for the period from 1946 through 1964 was 13.31 inches (Cook, 1958 and

Table 1. Average monthly precipitation in inches, and precipitation during the study at Tintic Valley.

	10-yr Avg. 1956-1965	1966	1967	1968	1969
January	1.22	0.46	2.99	0.19	3.47
February	1.34	2.76	0.21	2.26	1.93
March	1.30	0.02	1.01	1.48	0.17
April	1.58	0.26	0.40	2.65	1.02
May	1.50	0.68	3.39	1.35	0.37
June	0.72	0.07	2.25	0.35	2.20
July	0.52	0.27	0.36	1.73	0.46
August	1.35	1.22	1.15	1.80	0.94
September	0.70	1.12	1.06	0.03	
October	0.62	0.98	0.18	1.68	
November	1.08	1.83	1.21	0.84	
December	1.06	1.99	1.67	0.95	
Total	12.99	11.66	15.88	15.31	

1966). About 30 percent of this falls as snow from December through February. The remainder comes in erratic rain showers during spring, summer, and fall. Forty percent of these showers occur during March, April, and May. Precipitation varied greatly during the period of seed germination and early growth (Table 1). This had a great effect on seedling establishment.

Cache Valley

The Cache Valley study area is located on Utah Fish and Game Commission land near Green Canyon at the northeastern edge of the Logan city limits. This area lies at an altitude of 4,800 feet and occupies a strip between the Cache National Forest boundary and cultivated lands below.

The soil is a Timpanogos silt loam containing 27% sand, 52% silt, and 21% clay. The pH is 7.5, organic matter content of the upper 12 inches is 3.1%, and total soluble salt content is 0.06%. The profile becomes more sandy with increasing depth and coarse gravel deposits are common at three to four feet.

Native vegetation consists of big sagebrush, rabbitbrush (*Chrysothamnus nauseosus* (Pall.) Britton), balsamroot (*Balsamorhiza sagittata* (Pursh) Nutt.), helianthella (*Helianthella uniflora* (Nutt.) Torr. and Gray), yarrow (*Achillea lanulosa* (Nutt.) Piper), mule's ear (*Wyethia amplexicaulis* (Nutt.) Nutt.), beardless wheatgrass (*Agropyron spicatum* var. *inerme* (Scribn. and Smith) Heller), Kentucky bluegrass

(*Poa pratensis* L.) Sandberg bluegrass (*Poa sandbergii* *Vasey*), and Junegrass *Koeleria cristata* (L.) Pers.), (Smith, 1949).

Average annual precipitation for Logan is 16.64 inches (Table 2). Most of the moisture available for plant growth is that stored from winter precipitation (Table 2). Precipitation during the 137-day growing season, May 7 through October 11, is light.

Temperatures during July average 73.1° F, and a maximum of 102° F has been recorded. January average temperature is 24.3° F, and a minimum of -25° F has been recorded (U. S. Weather Bureau Records).

Curlew Valley

The Curlew Valley study area is located 20 miles west of Snowville, Box Elder County, Utah. The study area was on the upper edge of the valley floor at an elevation of 4,700 feet.

The soils have been described in detail by Gates, Stoddart, and Cook (1956). These soils range in pH from 7.8 to 8.5. Organic matter content is relatively low. Surface texture varies from loam to silty clay loam.

Study plots were located in a big sagebrush community. In its native condition, this sagebrush community was dominated by big sagebrush, with squirreltail, Indian ricegrass, western wheatgrass, and other drought-tolerant species filling interspaces between sagebrush plants. However, due to

Table 2. Average monthly precipitation in inches, and monthly precipitation during the study on the Utah State University campus (U. S. Dept. Commerce, 1940-1969).

	1940-1969 Average	1967	1968	1969
January	1.67	1.63	1.34	3.31
February	1.39	.74	2.66	2.99
March	1.81	3.30	2.77	.29
April	2.11	4.46	2.00	1.80
May	1.86	1.95	1.37	.15
June	1.26	3.56	3.22	3.51
July	.39	.37	.11	.54
August	.74	.11	3.44	.63
September	.89	.12	.32	.60
October	1.41	1.90	2.03	1.46
November	1.56	.62	1.88	.32
December	1.55	2.36	1.32	1.25
Total	16.64	21.12	22.46	16.85

[1]1967, 1968, and 1969 data were collected during this study.

a deteriorated condition, the area contained halogeton (Halogeton glomeratus (Bieb.) C. A. Meyer), cheatgrass (Bromus tectorum L.), Russian thistle (Salsola kali L.), and peppergrass (Lepidium perfoliatum L.) in interspaces between sagebrush plants.

Precipitation in the locality is low and erratic. Forty percent of the annual precipitation falls as snow, and 30 percent falls in May and June (Table 3). Average annual precipitation from 1960-1970 was 9.6 inches. During the study, precipitation was above average in 1965, spring 1967, and late summer 1968; it was below average in 1966, summer and fall 1967, and spring 1969.

Temperatures in the area average 23° F in January and 73° F in July. The maximum recorded temperature is 101° F, and the minimum is 26° F. The average length of growing season is 125 days, with the last killing frost in spring on May 25, and first killing frost in fall on October 1 (U. S. Dept. Commerce, 1940-1969).

Table 3. Average monthly precipitation in inches, and monthly precipitation during the study at Curlew Valley.

	1960-70 Average	1965	1966	1967	1968	1969
January	.6	.6	.1	.5	.5	1.1
February	.7	.4	.4	.4	1.0	1.5
March	.7	.6	.3	1.3	.7	.7
April	.7	1.2	.1	1.4	.4	.3
May	1.3	.8	.9	1.0	1.4	.1
June	1.5	1.3	.6	4.4	1.6	1.4
July	.6	1.2	.1	1.5	.6	.2
August	.9	3.1	.4	0	3.5	.1
September	.6	.2	.2	.4	.7	.1
October	.6	.1	0	.1	.7	1.1
November	.8	2.6	.9	0	.3	.6
December	.8	.6	.8	.6	1.3	1.0
Total	9.6	12.6	4.9	11.7	12.5	8.6

METHODS AND PROCEDURES

The Russian wildrye and crested wheatgrass clipping study at Curlew Valley was initiated in 1964, but the author did not take it over until 1967. The seeding at Eureka was initiated in the fall of 1966, and the author took it over in the spring of 1967. All other parts of this research were initiated and carried out by the author.

All data were punched on computer cards, and much data summary was done by computer. Analyses of variance were run to determine whether differences occurred between treatments. Sources of variation, degrees of freedom, mean squares, and results of F tests appear in the appendix. Differences between individual treatment means were determined by Duncan's multiple range tests, and are reported in the results section.

Greenhouse Studies

Competition between Russian wildrye and four weeds

Interspecific competition between Russian wildrye and cheatgrass, Russian thistle, halogeton, and peppergrass was studied during winter 1968. A factorial randomized block design with four replications was used. Russian wildrye and each weed species were planted in 12" X 10-1/2" X 12" pots in sandy loam soil under both saline and non-saline conditions. Russian wildrye was maintained at two plants per pot and weeds were maintained at zero, 2, 10, and 50 plants per pot.

The study was conducted under limited moisture conditions. Pots were watered to field capacity at planting, then given 1/8" water daily the first week of growth, 1/8" every other day the second week, 1/8" twice weekly the third week, and thereafter 1/4" per week. Moisture blocks in replications I and III helped maintain pots above the wilting point.

Soil for this study was taken from selected saline and non-saline topsoils in the field. Gates, Stoddart, and Cook (1956) described the vegetation and soils in the area where the soils were obtained.

At the time of collection of the soil, samples were collected and taken to the USU soils laboratory for analysis. The saline soil had a pH of 7.8, contained 1.8% total soluble salts, and contained 13% sand, 61% silt, and 26% clay. The non-saline soil had a pH of 7.9, contained 0.07% total soluble salts, and contained 14% sand, 56% silt, and 30% clay.

Summer conditions were simulated, since the study was conducted during winter. Artificial lighting was used to maintain a day length of fourteen hours during the first month and sixteen hours during the remainder of the study. Temperatures ranged between 70° F to 105° F during daytime and 42° F to 72° F at night.

Data were collected on all treatments at two separate dates because half of the greenhouse was needed for other work before the study was completed. Data collected on Russian wildrye seedlings included seedling emergence, vegetative dry weight per plant, average number of vegetative stems per plant, and average stem height per plant. All pots with saline soil were removed because of difficulty in keeping this soil watered. The saline soil shrunk away from the sides of the pots and allowed water to run out the bottom before wetting the pot. Many weeds had ceased growth in the saline soil at the time. Production data were not collected on plants growing in saline soil because obtaining production data on remaining treatments was difficult.

Competition between Russian wildrye and combinations of weeds

During summer 1968 a study was conducted in which combinations of three weedy species were placed in competition with Russian wildrye. Watering was the same as that in the previous study. Only non-saline soil was used. Four replications of each treatment were used. Treatments were as follows: (1) cheatgrass, Russian thistle, and peppergrass at two, ten, and fifty plants per pot; (2) cheatgrass plus Russian thistle, cheatgrass plus peppergrass, and Russian thistle plus peppergrass at one, five, and twenty-five plants of each species of the combination per pot; (3) cheatgrass plus Russian thistle plus peppergrass at one, four and seventeen plants of each species of the combination per pot; and (4) controls with twenty-five Russian wildrye per pot. Twenty-five Russian wildrye seeds were planted in a row across each treatment.

After two weeks, emergence data were taken. Final data collection was made in September. Similar measurements were taken on Russian wildrye and the weedy species in both the winter and summer studies.

No artificial lighting was used. Normal daylengths caused phenology to be similar to that in the field. Temperatures ranged between 54° F and 70° F at night and 70° F and 102° F during daytime.

<u>Replacement series and intraspecific competition</u>

A study was conducted during spring 1969 to determine intraspecific and interspecific competition with Russian wildrye and four weeds using the replacement series described by Palmblad (1966). The replacement series consists of placing two species in competition and varying numbers of plants of each species while holding constant number of plants per unit area. Treatments were combinations of Russian wildrye and either cheatgrass, halogeton, peppergrass, or Russian thistle as follows: (1) no Russian wildrye plus 50 weeds, (2) 13 Russian wildrye plus 37 weeds, (3) 25 Russian wildrye plus 25 weeds, (4) 37 Russian wildrye plus 13 weeds, (5) Russian wildrye plus no weeds, (6) one Russian wildrye plant, and (7) one weed plant.

Four more treatments were included to determine intraspecific competition between Russian wildrye plants. By using one treatment from the series, five treatments were compared: 1, 13, 25, 37, and 50 Russian wildrye plants per pot.

A randomized block design was used with three replications and three samples per replication. Gallon sized cans were used for pots. Non-saline sandy-loam soil was used. Data collection was made after weed maturity on: plant height, leaf length, number of leaves per tiller, number of tillers per plant, and weight of above-ground dry matter per pot. Data were collected for both species in each pot.

Moisture use

A moisture use study was conducted on Russian wildrye, crested wheatgrass, cheatgrass, halogeton, peppergrass, and Russian thistle. The following treatments were set out in a randomized block design with three replications and three samples per treatment: (1) no plants--to determine evaporation loss, (2) Russian wildrye, (3) crested wheatgrass, (4) cheatgrass, (5) halogeton, and (6) Russian thistle.

Sandy loam soil was oven-dried and weighed for each gallon pot. Field capacity and wilting percentage were determined for the soil using a pressure membrane. Water was weighed into the pots to bring them to field capacity. Twenty seeds of each species were planted in each pot to assure establishment of ten plants per pot.

Pots were weighed at varying intervals after germination to determine water loss. Each pot was brought back to field capacity at weighing. Phenological stage and plant height were recorded for each pot at weighing.

It was planned to maintain ten plants in each pot. As the plants grew, numbers of plants per pot were reduced. At the end of the study, the following numbers of plants of each species remained in each pot: Russian wildrye--6, Fairway crested wheatgrass--5, cheatgrass--1, halogeton--15; peppergrass--6, and Russian thistle--7. Plants were removed as needed to maintain uniform water use over all pots. Records were kept of weight of plant material removed each time. It was not necessary to keep numbers of plants equal, since final comparison is in grams of water used to produce a gram of herbage.

Temperatures varied between 70° F and 110° F during daytime, and 48° F to 76° F at night. Soil temperatures measured in a control pot at the one-inch depth varied from 60° F to 90° F.

Similar methods of determining moisture use have been used by others. Hunt (1962) used the same procedure, except that he used rooted tillers from established plants, rather than starting from seed. Hull (1963a) used a similar procedure, except that he grew more than one species in one pot while determining moisture use.

Moisture levels

The effect of moisture level on emergence of Russian wildrye was studied during July 1969. This experiment contained nine moisture levels: 2.5, 3.5, 4.5, 7.0, 9.0, 11.0, 13.0, 15.0, and 17.0 percent soil moisture. Each treatment contained 10 replications. Each pot was filled with the same amount of sandy loam soil. Twenty-five Russian wildrye seeds were planted in each pot. A predetermined amount of water was weighed into each pot to bring it to the desired percentage. Moisture levels were maintained throughout the study by weighing and watering daily. After first emergence, emerged plants were counted at two-day intervals for 21 days. At the end of the study, plant height and number of leaves per plant were measured for each pot.

Depth of planting

The effect of depth of planting on emergence of Russian wildrye was studied during July 1969. Treatments consisted of planting at seven depths: surface, covered 1/8, 1/4, 1/2, 1, 2, and 4 inches. A completely randomized design with ten samples (reps) per treatment was used. Twenty-five seeds were placed randomly in each pot. After planting, pots were watered to field capacity and maintained as close to this moisture level as possible throughout the study. A known amount of soil was placed in each pot, and pots were weighed daily and rewatered to field capacity.

Data collection included counting the number of seedlings growing daily after emergence began and measuring plant height.

Field Studies

1967 Eureka seeding

At the Tintic Valley Cooperative Research Area a study of methods, rates, seasons, and seed types in planting Russian wildrye was initiated. Seeds were drilled and broadcast with a grain drill equipped with semideep, single disc footpieces set for 12" row spacings. Planting depth varied from 1/4" to 1". Broadcasting was done by removing the spouts from the disc footpieces and allowing the seed to fall onto the bare ground. Six, nine, and twelve pounds of seed per acre were planted by both methods. Both commercial and Vinall seed were planted at each rate and by each method during fall (October 20, 1966) and spring (April 16, 1967).

A factorial randomized block design with three replications was used. The experimental area had been plowed the previous summer with a brushland plow to prepare the seedbed.

Data collection was done in 1967, 1968, and 1969. Seedling counts were made in July and September 1967 in ten randomly located 0.96 sq. ft. circular frames in each plot. The number of weeds in each frame was estimated. In August 1968 vigor and production data were taken in ten randomly located 9.6 sq. ft. circular frames in each plot including plant height, leaf length, number of tillers per plant, number of leaves per tiller, and number of plants per frame. Percent weed cover was estimated in each frame. In July 1969 vigor and production were taken in twenty randomly located 9.6 sq. ft. frames in each plot including plant height, long and short crown diameter, leaf length, number of seedheads per plant, and number of plants per plot. Percent weed cover was estimated in each frame. Vigor measurements were made on the plant closest to the center of the 9.6 sq. ft. frame.

1969 Eureka seeding

During 1969, a study was initiated to determine a better method of establishing Russian wildrye at the Tintic Valley Cooperative Research Area. Both spring and fall plantings were made of the following treatments in a factorial randomized block design with three replications: (1) three rates of seeding--6, 12, and 24 pounds per acre and (2) three rates of broadcast nitrogen fertilizer--15, 30, and 45 pounds per acre.

Data collection was limited because of poor soil moisture. No germination occurred in the fall and very little germination occurred in the spring. To salvage some information, fifteen seed samples were dug in each of the rate-of-seeding treatments. One-foot sections of drill-row were randomly located within the plot and were excavated to a depth of one inch and to one inch on either side of the drill row. Samples were taken to the lab, seed was separated from the soil by sieving, Russian wildrye seed was removed and treated with Captan, and seeds were germinated in the growth chamber in petri dishes.

Phenology and root growth

Phenology of Russian wildrye, cheatgrass, Russian thistle, halogeton, and peppergrass seedlings were studied by a method similar to that used by Harris (1965). Similar root studies using glass tubes or glass-sided boxes have been conducted by Lawrence (1963) and Hull (1963a). Fairway crested wheatgrass was used as a control because of widespread use and knowledge of the species.

During 1968 and 1969 individual plants of each species were established in each of ten plastic tubes, three inches in diameter and four feet long. The tubes were arranged in holes slightly tilted from the vertical so the roots grew against the side for observation (Figure 2). Five seeds were planted in each tube. The plants were thinned to one per tube after emergence. The tubes were arranged so the tops were slightly above and the soil surface in the tube was even with the soil surface in the experimental area. A sandy loam soil was used in the tubes.

Measurements taken on individual plants at bi-weekly intervals in 1968 and at weekly intervals in 1969 included average number of vegetative tillers, average stem heights, average leaf length, average number of leaves per tiller,

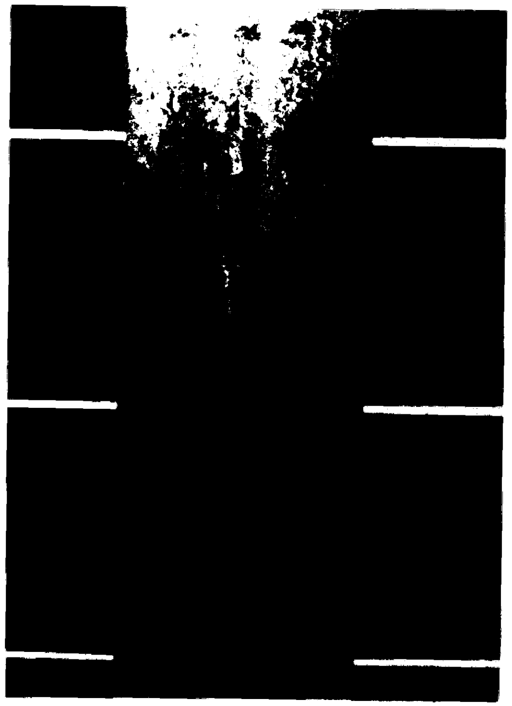

Figure 2. View of root study tube showing roots growing against tube.

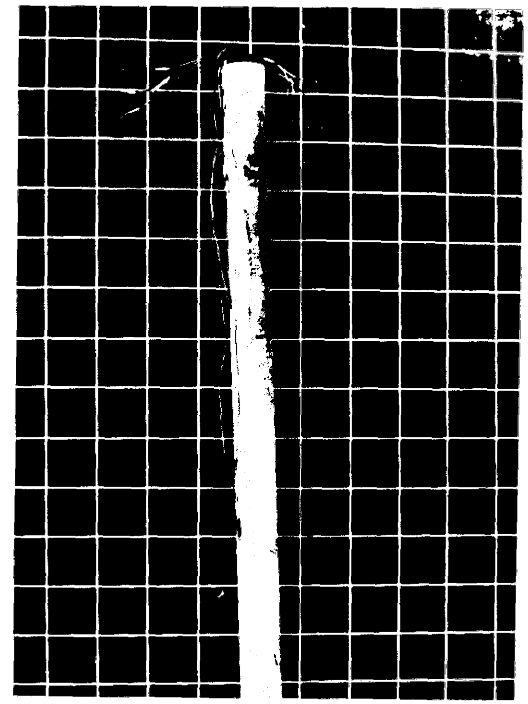

Figure 3. View of root study tube showing leads to thermistors and moisture blocks.

and an index to root density. The root density index was based on the percent of the tube surface covered with live roots. Ratings were given as follows: 0, no roots; 1, 1-10%; 2, 11-20%; 3, 21-30%; 4, 31-40%. Soil moisture and temperature were measured at depths of 3, 9, 18, and 30 inches with thermistors and moisture blocks installed in the tubes and read at weekly intervals (Figure 3).

Competition

A study of interspecific competition between Russian wildrye and cheatgrass, Russian thistle, halogeton, and peppergrass was conducted in 1968. Russian wildrye and one weed were planted in 15' X 15' plots near Green Canyon, north of Logan, in a randomized block design with four replications. Russian wildrye was planted at eight pounds per acre in twelve-inch rows. A control plot of Russian wildrye alone was seeded at the eight-pound rate. Crested wheatgrass was planted at eight pounds per acre in twelve-inch rows as a standard for comparison. In each treated plot the number of weed seeds planted was equal to the number of Russian wildrye seeds.

The seedbed was roto tilled in the fall. To control the influence of foreign species, 2, 4-D was applied on cheatgrass plots; hand removal of foreign species was used on all other plots.

Soil moisture blocks and thermistors were placed in each plot at depths of three, nine, eighteen, and thirty inches. Moisture and temperature data were recorded at weekly intervals.

Data collected on Russian wildrye seedlings included seedling survival, vegetative dry weight per plant, average number of vegetative tillers per plant, average stem height, average leaf length, and average number of leaves per tiller. Data collected on the weed species included average plant height and average number of plants per plot. Data were collected after the weeds had matured.

Snowville Russian Wildrye-Crested Wheatgrass Clipping Study

A study of the effects of seasons and intensities of clipping on two stand densities of Russian wildrye and crested wheatgrass was conducted in Curlew Valley from 1964 to 1969. Clipping was done in 1964, 1965, 1966, 1967, and 1968. Data collections were made in 1965, 1966, 1967, 1968, and 1969. Five plants of each species in both thick and thin stands were clipped at three intensities (25, 50, and 75 percent) during four seasons--early (April 17), mid (May 22), late (June 26), and early and late (April 17 and June 26). Each treatment was replicated four times.

Clipped samples from individual plants were placed in individually numbered bags, air dried, and weighed to determine production. Vigor measurements taken prior to clipping included plant height and number of seedheads. Vigor measurements taken after frost each year included plant height, number of seedheads, crown diameter, and crown density rating. Control plants were not clipped, but production was taken by ocular estimate.

During 1969 plants were allowed to recover and production and vigor measurements were taken. Production was taken by ocular estimate both for the treated plant and for a 9.6 sq. ft. circular area with the treated plant as its center. Vigor measurements included long and short crown diameter, plant height, leaf length, crown density, number of seedheads, and number of plants per plot.

All data were collected by a crew of five graduate and undergraduate students under the direction of the graduate student in charge of the project. Crews and crew leaders varied during the course of the study.

Prior to each data collection, the crew leader would train crew members on each measurement to be taken. Each training session lasted from 30 to 45 minutes. Most of the time was spent training crew members to clip properly, i.e., 25, 50, or 75 percent of current growth. All plants within a surrounding 9.6 sq. ft. circular frame were clipped to the same intensity as the treatment plant. Each treatment plant lay within the "V" of an angle iron stake. The stake marked the center of the 9.6 sq. ft. frame.

Crown diameter was measured across both the long and short diameters of the plant crown. When data were tabulated, long and short diameters were added, and the sum was used as an index for comparison between treatments.

Crown density ratings were obtained by making an ocular estimate of the percent live growth within the crown of the plant. Estimates were recorded according to the following scale: 0--plant completely dead, 1--10% live growth, 2--20% live growth, 3--30% live growth, 4--40% live growth, 5--50% live growth, 6--60% live growth, 7--70% live growth, 8--80% live growth, 9--90% live growth, and 10--100% live growth.

RESULTS

Greenhouse Studies

Competition between Russian wildrye and four weeds

Data were collected at two dates during this study. The purpose of the first data collection was to determine the effect of saline soil on emergence. Saline soil significantly reduced both emergence and vigor of Russian wildrye (Table 5). An average of 3.3 seedlings emerged in saline soil, and 7.7 in non-saline soil. Differences between other treatments were not apparent until the second data collection (compare Tables 4 and 5).

Russian thistle and cheatgrass caused greatest reductions in production (Table 5). Peppergrass at 2 and 10 plants per pot only slightly reduced production of Russian wildrye. Halogeton appears not to be a severe competitor, but due to difficulty in maintaining the desired number of halogeton plants in each pot, these figures may not be representative. At 50 plants per pot, the other three species reduced Russian wildrye production 90 percent of more (Table 5).

Russian wildrye production was reduced to 1/2, 1/3, and 1/6 that of controls by competition from two, ten, and fifty weeds, respectively (Table 5). Plant height was reduced significantly by competition from 50 weeds. Reductions

Table 4. Comparison of the effects of weed competition on emergence and vigor of Russian wildrye on saline and non-saline soils in 0.96 sq. ft. pots in the greenhouse in 1967 after six weeks of growth.[1]

Species	Weed density	Saline		Non-saline	
		Plant ht. (cm)	% emergence	Plant ht. (cm)	% emergence
Control	0	13.0	35.8	19.9	82.5
Cheatgrass	2	12.6	33.3	18.3	79.2
	10	9.5	20.8	14.8	71.7
	50	11.6	42.5	14.9	62.5
Halogeton	2	12.5	28.3	20.3	79.2
	10	12.6	47.5	18.6	71.7
	50	12.4	36.7	19.8	83.3
Peppergrass	2	9.7	32.5	18.9	81.7
	10	10.6	27.5	18.6	78.3
	50	10.4	26.7	19.1	79.2
Russian thistle	2	12.3	35.0	17.6	82.5
	10	10.8	40.8	18.5	82.5
	50	12.8	27.5	18.3	68.3

[1]For statistical analysis of this data, see Appendix Table 22.

Table 5. Vigor and production of Russian wildrye in competition with four weeds at three densities in the greenhouse in 1967 after three months of growth.[1]

Species	Weed density	Plant height (cm)	No. leaves/ tiller	No. tillers/ plant	Leaf length (cm)	Grams dry matter
Control	0	23.3^{a}[3]	4.0^{a}	5.2^{a}	19.3^{a}	1.6^{a}
Cheatgrass	2	20.1^{a}	3.4^{b}	3.5^{bc}	16.8^{ab}	0.7^{b}
	10	16.4^{bc}	3.5^{ab}	2.1^{d}	14.3^{c}	0.3^{c}
	50	15.8^{c}	2.8^{c}	1.7^{e}	13.0^{c}	0.3^{c}
Halogeton	2	21.9^{ab}	3.8^{ab}	4.4^{ab}	17.7^{a}	1.1^{ab}
	10	20.5^{ab}	3.8^{ab}	3.8^{bc}	17.8^{a}	0.8^{b}
	50	19.0^{a}	3.3^{b}	3.5^{bc}	15.6^{ab}	0.7^{b}
Peppergrass	2	22.3^{a}	3.8^{ab}	4.9^{ab}	17.5^{a}	1.4^{ab}
	10	21.2^{ab}	3.8^{ab}	4.3^{ab}	18.9^{a}	1.3^{ab}
	50	21.8^{ab}	3.7^{ab}	2.5^{d}	18.1^{a}	0.3^{c}
Russian thistle	2	19.7^{a}	3.3^{b}	3.0^{cd}	16.8^{ab}	0.4^{c}
	10	19.8^{a}	3.1^{bc}	2.8^{cd}	16.6^{ab}	0.3^{c}
	50	17.8^{bc}	3.3^{b}	2.3^{d}	15.2^{ab}	0.2^{c}

[1]For statistical analysis of this data, see Appendix, Table 23.

[2]Number of weeds per 0.96 sq. ft. pot.

[3]A significant ($P<0.05$) difference occurs between two means not followed by the same letter.

in leaves per tiller, tillers per plant, and leaf length were not as drastic. Tillering was reduced significantly by all densities of weeds.

Cheatgrass and Russian thistle had the greatest effect on vigor (Table 5). Height of Russian wildrye was reduced most by cheatgrass competition. Tillering was reduced by half by cheatgrass and Russian thistle competition, and was reduced significantly by peppergrass and halogeton competition. Peppergrass and halogeton had least effect on vigor of Russian wildrye.

Competition between Russian wildrye and combinations of weeds

Combinations of two and three species caused greatest reductions in production (Table 6). Russian thistle and cheatgrass were the most severe competitors in single species stands. Production of Russian wildrye was reduced 61% by competition with two species and 72% by competition with three species of weeds. Combinations containing cheatgrass caused greatest reductions in production. Peppergrass and Russian thistle combined at two weeds per pot caused less reduction in production than Russian thistle alone at the same density.

Plant height and leaf length were reduced by competition from 50 weeds (Table 6). Tillers per plant were reduced to 1/2 and 1/3 that of controls by competition from two and fifty weeds, respectively.

Table 6. Vigor and production of Russian wildrye in competition with three weeds and combinations of weeds in the greenhouse in 1968.[1]

Species or combination	No. weeds/ 0.96 sq. ft. pot	Plant height (cm)	Leaf length (cm)	No. tillers/ plant	No. leaves/ tiller	Dry weight (grams)
Control	0	18.9^{a}[2]	14.8^{a}	4.1^{a}	4.2^{a}	2.5^{a}
Cheatgrass (1)	2	16.7^{ac}	13.0^{a}	2.9^{b}	4.4^{a}	1.6^{b}
	10	14.0^{cg}	11.7^{be}	1.7^{ce}	4.1^{a}	0.7^{bh}
	50	11.6^{fg}	9.3^{ef}	1.4^{e}	3.3^{a}	0.4^{h}
Peppergrass (2)	2	17.8^{ab}	14.0^{ab}	3.1^{b}	4.6^{a}	1.7^{b}
	10	15.2^{af}	12.4^{ac}	2.3^{bd}	4.7^{a}	1.2^{ce}
	50	12.9^{dg}	10.9^{bf}	1.5^{de}	4.1^{a}	0.8^{efgh}
Russian thistle (3)	2	14.4^{bg}	12.3^{ad}	2.5^{bc}	4.4^{a}	1.1^{df}
	10	13.9^{cg}	11.0^{bf}	1.7^{ce}	4.0^{a}	0.7^{fh}
	50	12.4^{dg}	8.9^{f}	1.3^{e}	4.0^{a}	0.6^{gh}
1 + 2	2	13.2^{cg}	10.5^{bf}	1.9^{ce}	4.1^{a}	0.7^{fh}
	10	13.4^{cg}	10.2^{cf}	1.8^{ce}	4.3^{a}	0.8^{efgh}
	50	13.4^{cg}	11.2^{bf}	1.3^{e}	3.8^{a}	0.4^{h}
1 + 3	2	14.1^{cg}	10.3^{bf}	1.8^{ce}	4.5^{a}	0.7^{fh}
	10	15.3^{ae}	11.5^{bf}	1.5^{de}	4.0^{a}	0.7^{bh}
	50	11.5^{g}	8.9^{f}	1.3^{e}	3.7^{a}	0.5^{gh}
2 + 3	2	15.7^{ad}	12.4^{ac}	3.1^{b}	4.3^{a}	1.5^{bd}
	10	12.4^{dg}	9.8^{cf}	1.6^{de}	4.3^{a}	0.6^{gh}
	50	12.6^{dg}	10.5^{bf}	1.3^{e}	4.2^{a}	0.6^{gh}
1 + 2 + 3	2	12.3^{dg}	9.6^{df}	1.5^{de}	4.1^{a}	0.7^{fh}
	10	14.0^{cg}	10.3^{bf}	2.0^{ce}	3.8^{a}	0.9^{efg}
	50	11.7^{eg}	9.0^{eg}	1.6^{de}	3.8^{a}	0.5^{gh}

[1]For statistical analysis of this data, see Appendix, Table 24.

[2]A significant ($P \angle 0.05$) difference occurs between two means not followed by the same letter.

Intraspecific competition

Russian wildrye was planted at densities of 1, 13, 25, 37, and 50 plants per pot. Production first increased as density increased, then decreased at the highest density (Table 7). At 37 plants per pot, production was almost twice as high as at one plant per pot. There were no differences in production at 13, 25, and 50 plants per pot. At these three densities, production was almost 1.5 times higher than at one plant per pot. Production per Russian wildrye plant decreased as density increased. Per plant production at 13 plants per pot was only 1/10 that at one plant per pot.

The four weeds were planted in single-species stands at 1, 25, and 50 plants per pot. Halogeton and Russian thistle produced more herbage than any other species (Table 8). Russian wildrye and peppergrass produced less aboveground material than other species. Cheatgrass was intermediate in herbage production. Production increased as density of Russian wildrye, halogeton, and Russian thistle increased. Cheatgrass and peppergrass production first increased, then decreased at 50 plants per pot. Production per plant of all species decreased as density increased.

Interspecific competition using the replacement series

Russian wildrye alone produced significantly more herbage than when grown with a weed (Table 8). The most severe reduction in production, 75%, was caused by cheatgrass.

Table 7. Production of Russian wildrye and four weeds grown in gallon pots at three densities in single species stands in the greenhouse during 1968.[1]

Species	Number plants per pot: 50	25	1	
	Grams dry matter			Average
Russian wildrye	1.5	1.4	1.1	1.3[c][2]
Cheatgrass	4.0	4.2	1.8	3.3[b]
Halogeton	13.1	10.8	3.1	9.0[a]
Peppergrass	1.5	2.3	1.1	1.6[c]
Russian thistle	9.1	8.3	8.0	8.4[a]

[1]For statistical analysis of this data, see Appendix, Table 25.

[2]A significant difference ($P < 0.05$) occurs between two means not followed by the same letter.

Table 8. Grams of Russian wildrye produced in competition with four weeds in the greenhouse in 1968, using the replacement series.[1]

Species	Number of plants: 50[2]-0[3]	37[2]-13[3]	25[2]-25[3]	13[2]-37[3]	Average
Control[4]	1.5	2.0	1.4	1.4	1.6[a]
Cheatgrass		0.7	0.4	0.2	0.4[d]
Halogeton		1.1	1.1	0.9	1.0[c]
Peppergrass		1.3	1.0	0.8	1.0[c]
Russian thistle		1.7	1.3	0.8	1.3[b]
Average	1.5	1.2[a]	1.0[a]	0.7[b]	

[1]For statistical analysis of this data, see Appendix, Table 25.

[2]Number of Russian wildrye plants.

[3]Number of weeds.

[4]Number of Russian wildrye indicated, with no weeds.

Halogeton, peppergrass, and Russian thistle caused 37.5%, 37.5% and 19.7% reductions in Russian wildrye production, respectively. At 37 plants per pot, Russian wildrye in competition with 13 Russian thistle plants produced more than 50 Russian wildrye plants alone.

In this experiment, densities of halogeton were maintained as desired. Plant height, leaf length, and number of leaves per tiller were greater on Russian wildrye plants grown in competition with halogeton than with no weeds at all (Table 9).

Table 9. Effect of species of weed on vigor and production of Russian wildrye using the replacement series in the greenhouse during 1968.

Species	Weed weight (grams)	Measurements for Russian wildrye				
		Height (cm)	Leaf length	Leaves/ tiller	Tillers/ plant	Weight[1]
Russian wildrye	0	13.5	12.6	5.0	1.6	1.6
Cheatgrass	2.4	10.3	7.7	5.0	1.0	.4
Halogeton	9.0	17.2	14.3	5.2	1.2	1.0
Peppergrass	1.2	12.8	9.9	5.2	1.0	1.0
Russian thistle	3.2	12.2	10.1	4.9	1.0	1.2

[1]For statistical analysis of this data, see Appendix, Table 25.

Increased weed density resulted in increases in Russian wildrye plant height, leaf length, and number of tillers per plant (Table 10). When compared to controls, however, marked decreases occurred on all vigor measurements except leaves per tiller. Production per plant declined with increased weed density. However, production per plant was similar between the heaviest weed competition treatment (0.03g) and the heaviest competition among Russian wildrye plants (0.05g).

Table 10. Effect of density of weed on vigor and production of Russian wildrye using the replacement series in the greenhouse during 1968.[1]

		Measurements for Russian wildrye					
Treatment	Weed weight (grams)	Height (cm)	Leaf length (cm)	Leaves/ tiller	Tillers/ plant	Weight total (grams)	Weight per plant (grams)
13[2]-37[3]	5.1	13.7	11.0	5.0	1.1	0.7	0.05
25-25	3.8	13.4	10.8	5.1	1.0	0.9	0.04
37-13	1.9	12.5	10.1	5.0	1.0	1.2	0.03
13-0	0	15.6	13.2	5.0	2.5	1.4	0.11
25-0	0	11.6	10.0	5.0	1.3	1.4	0.11
37-0	0	13.2	10.8	5.0	1.0	2.0	0.05

[1]For statistical analysis of this data, see Appendix, Table 26.

[2]Number of Russian wildrye plants.

[3]Number of weeds.

Moisture use

Highly significant differences occurred between species in amount of water required to produce a gram of dry matter (Table 11). Water use was highest for Russian wildrye. Weeds were more efficient water users than introduced grasses. Peppergrass used significantly more water than other weeds. Total evaporation loss was 8,080 grams, greater than the amount transpired by any species. No attempt was made to shade the controls. Therefore, evaporation loss was probably higher than pots shaded with plants.

Table 11. Dry matter produced, total water used and amount of water used per gram of dry matter for six species of grasses and weeds grown in gallon pots in the greenhouse in 1969.[1]

Species	Total dry matter (grams)	Total water use (grams)	Grams H_2O per gram dry matter[2,3]
Russian wildrye	58	7567	130[a]
Crested wheatgrass	60	7148	118[a]
Peppergrass	72	4455	62[b]
Cheatgrass	124	6206	50[c]
Halogeton	151	4257	28[c]
Russian thistle	243	5605	23[c]

[1]For statistical analysis of this data, see Appendix, Table 27.

[2]A highly significant ($P \angle 0.01$) difference occurs between two means not followed by the same letter.

[3]Note that these values are corrected for moisture loss due to evaporation from control pots.

On a per plant basis (Table 12), it appears that cheatgrass is the least efficient water user. There was only one cheatgrass plant per pot, however, and there were fifteen halogeton plants per pot, so the only valid comparisons are among other species of comparable densities. Among comparable species, crested wheatgrass required more water per plant, followed by Russian wildrye, Russian thistle, and peppergrass, in that order.

Table 12. Grams of moisture used per plant per day (bi-weekly weighings) during the first growing season for six grasses and weeds grown in gallon pots in the greenhouse during 1969.[1]

	Species					
Days after start	Russian wildrye	Crested wheat-	Cheat-grass	Halo-geton	Pepper-grass	Russian thistle
18	0.2	0.4	1.5	0.1	0.2	0.2
32	0.8	0.3	1.9	0.1	0.9	0.3
49	2.9	5.0	13.9	0.5	4.0	3.2
63	6.4	10.3	29.0	0.6	7.9	9.4
76	4.7	10.4	26.4	1.1	7.4	7.6
91	9.0	12.2	34.9	2.3	10.8	8.6
105	10.1	13.4	49.3	2.6	8.0	7.8
119	9.6	13.4	51.1	2.6	3.8	7.5
133	10.8	13.7	52.0	2.5	2.4	6.7
146	4.5	4.8	7.1	0.9	0.3	1.9
164	2.8	3.4	9.0	0.6	0.5	0.6

[1]Values are corrected for evaporation loss by subtraction of loss from controls which had no plants growing in them.

One objective was to determine relative moisture use throughout the seedling stage. Since it was impossible to clip and weigh plants and continue using them, measurements of leaf length, leaf width, leaves per tiller, and tillers per plant were taken, and leaf area was calculated at weighing.

Data on moisture used per day per square centimeter of leaf area (Figure 4) indicate that Russian thistle was not the most efficient water user, but became progressively more efficient the older it got. Russian wildrye and crested wheatgrass had similar water requirements throughout

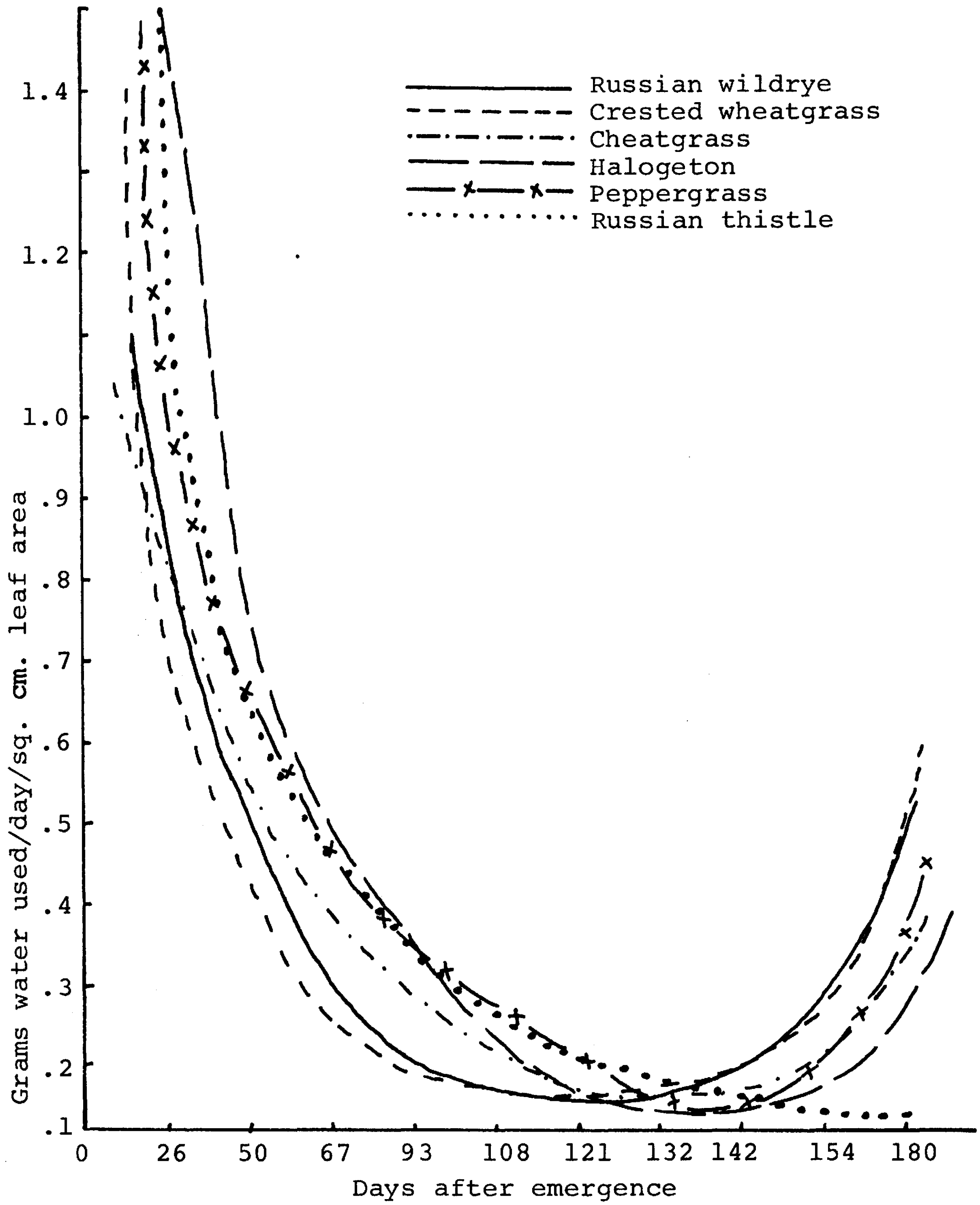

Figure 4. Grams of water used per day per square centimeter of leaf area by six species grown in gallon pots in the greenhouse during 1969.

early growth stages and both were more efficient than Russian thistle until later growth stages. Cheatgrass was the most efficient water user during rapid growth.

Moisture level

Russian wildrye was planted under nine different moisture levels, including 15 atmospheres and 1.3 atmosphere. Some emergence occurred at 7% moisture, 2% below wilting coefficient (Table 13). No emergence occurred below 7% moisture. In general, emergence and plant height increased with increasing soil moisture. Significant differences occurred between moisture levels in both total emergence and plant height. Highest emergence occurred at levels above wilting coefficient. No significant differences in emergence occurred between the four moisture levels above wilting coefficient (Table 13). After 19 days, plant height at high moisture levels was twice that at low moisture levels. There were more leaves per plant at high moisture levels than at low moisture levels.

Rate of emergence increased with increasing soil moisture (Figure 5). Earliest emergence occurred in the three highest moisture levels. No emergence occurred at 7, 9, and 11 percent moisture until one to two days later.

Depth of planting

Russian wildrye was planted at seven depths ranging from no seed coverage to four inches coverage. Percent emergence increased up to 1/4 inch, then decreased to

Table 13. Effect of moisture level on emergence of Russian wildrye grown in gallon pots in the greenhouse in 1969.[1]

% H_2O in Soil	% Emergence	Cm. plant height	No. leaves
2.5	0[d][4,5]	-	-
3.5	0[d]	-	-
4.5	0[d]	-	-
7.0	10[c]	5.0	2
9.0[2]	44[b]	5.6	2
11.0	69[a]	8.1	2
13.0	69[a]	9.1	2
15.0	60[b]	10.5	3
17.0[3]	73[a]	11.5	3

[1]For statistical analysis of this data, see Appendix, Table 28.

[2]Wilting coefficient (15 atm.)

[3]Field capacity (1/3 atm.)

[4]A significant ($P<0.05$) difference occurs between two means not followed by the same letter.

[5]Emergence counts were made every other day for 21 days; plant height and no. leaves were measured at end of period.

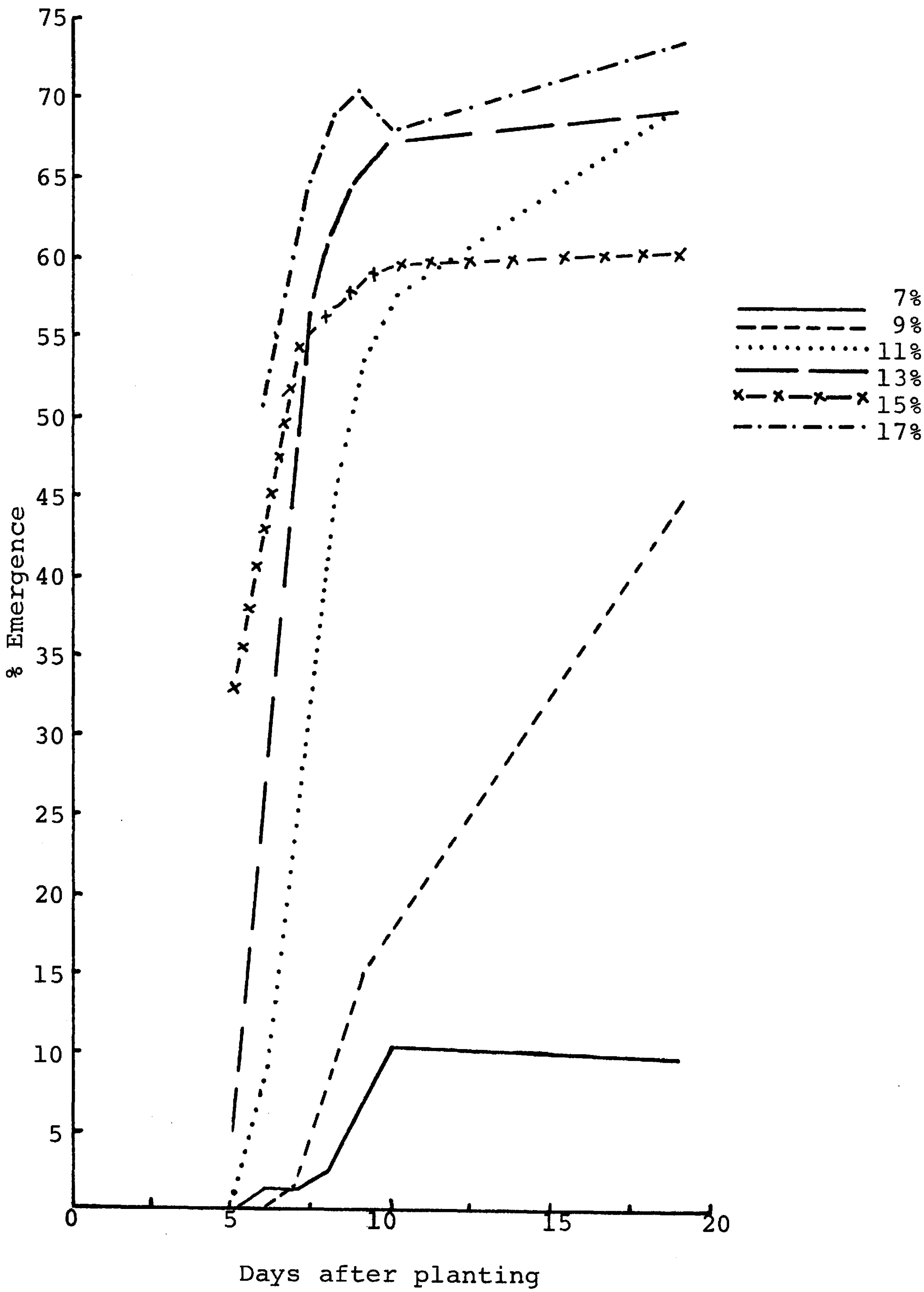

Figure 5. Rate of emergence of Russian wildrye grown in gallon pots in the greenhouse in 1969 under increasing levels of soil moisture.

zero at four inches (Figure 6). The 1/4-inch depth produced significantly more seedlings than at any other depth, although planting at 1/2 or 1 inch produced only about 5 percent less seedlings than planting at 1/4 inch. Planting on the soil surface produced significantly more seedlings than planting two inches deep.

Rate of emergence was greatest at the 1/4-inch depth (Figure 6). Emergence was slowest when seeds were not covered and where they were covered deepest, i.e., 1 and 2 inches.

Field Studies

1967 Eureka seeding

Plant survival data were collected during 1967, 1968, and 1969 on the fall 1966-spring 1967 seeding. During 1967 and 1968, significantly more seedlings were established by commercial seed than by Vinall seed (Table 14). Significantly more seedlings were established at the 9-pound per acre rate than at the 6-pound rate, and significantly more were established at the 12-pound rate than at either the 6- or 9-pound rate. Drilling produced significantly more seedlings during the first two growing seasons, but these differences were masked by the third growing season. No differences occurred between fall and spring planting. Density of plants decreased from 1.5 to 0.7 per sq. ft. from 1967 to 1969.

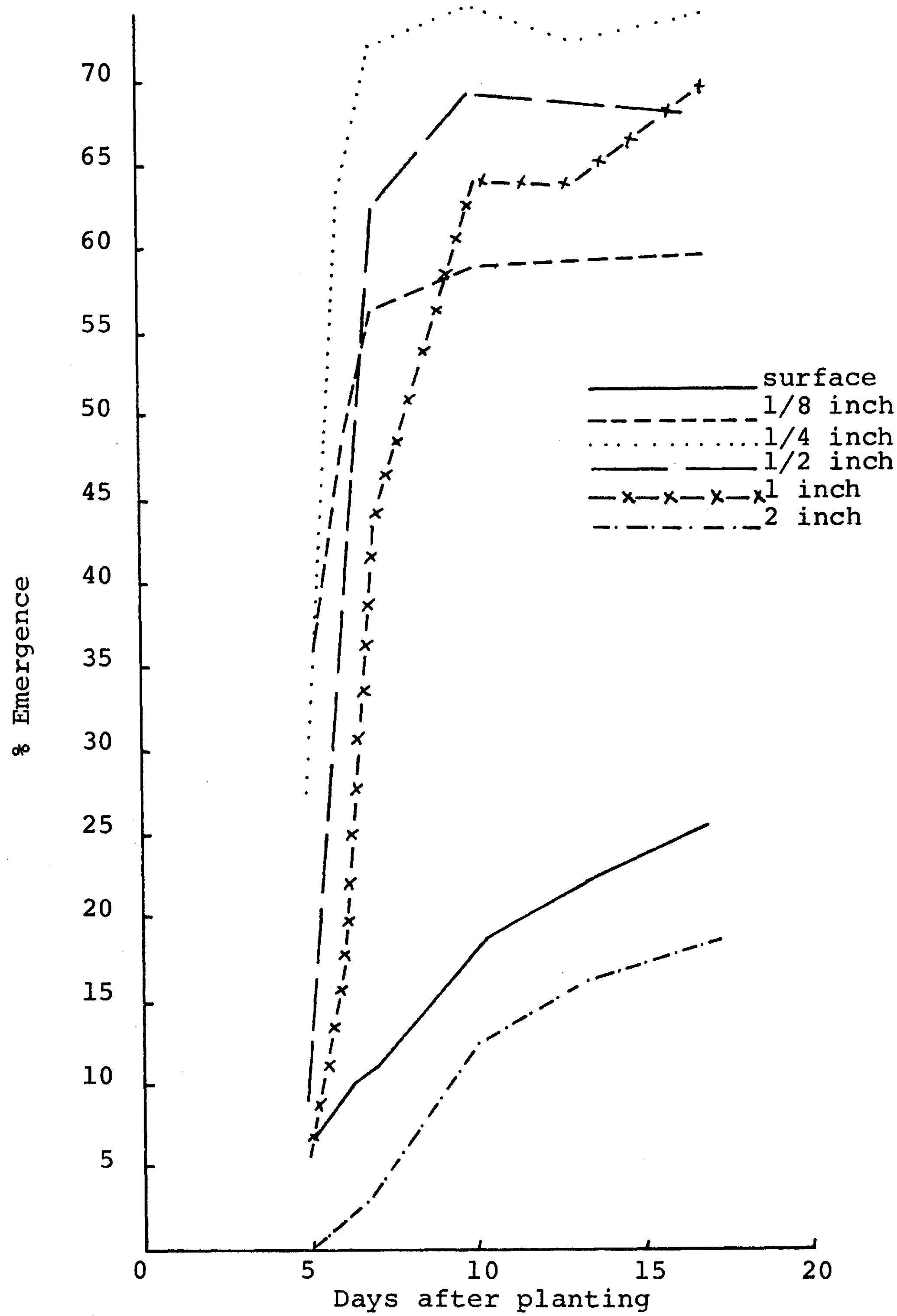

Figure 6. Rate of emergence of Russian wildrye at six depths of planting in gallon pots in the greenhouse in 1969.[1]

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[1] No emergence occurred at the four-inch planting depth.

Table 14. Average number of Russian wildrye plants per square foot and amount of weeds at three dates in Russian wildrye seeding made in 1966 and 1967 at Eureka.[1]

Treatment	1967		1968		1969	
	# El.ju.	# weeds	# El.ju.	% weed cover	# El.ju.	% weed cover
Commercial seed	1.7[a2]	1.5[a]	1.4[a]	32	0.8	28
Vinall seed	1.3[b]	1.7[a]	1.1[b]	26	0.6	30
6 #/ac	1.2[c]	1.5[a]	1.0[c]	34	0.6	30
9 #/ac	1.5[b]	1.6[a]	1.2[b]	28	0.7	28
12 #/ac	1.8[a]	1.7[a]	1.6[a]	25	0.8	26
Drilled	1.7[a]	1.6[a]	1.4[a]	31	0.7	27
Broadcast	1.4[b]	1.6[a]	1.1[b]	28	0.7	30
Fall 1966	1.5[a]	1.8[a]	1.3[a]	30	0.7	26
Spring 1967	1.5[a]	1.4[b]	1.2[a]	29	0.7	30
Overall average	1.5	1.6	1.25	29	0.7	28

[1]For statistical analysis of this data, see Appendix, Table 30.

[2]A highly significant ($P<0.01$) difference occurs between two means not followed by the same letter.

In 1968 no significant differences occurred between treatments on plant height, number of leaves per tiller, number of tillers per plant, or leaf length (Appendix, Table 31). Plants from commercial seed production significantly more herbage than those from Vinall seed. Production increased significantly with increased seeding rate. Drilling produced significantly more herbage than broadcasting. Fall planting produced significantly more than spring planting.

Final vigor measurements made in 1969 consisted of plant height, crown diameter, leaf length, number of seedheads, and production. By 1969, differences in herbage production due to methods and rates of planting had been masked (Table 16). However, fall planting and commercial seed produced significantly more herbage than spring planting or Vinall seed.

Table 15. Vigor data taken in 1969 on Russian wildrye seeding made at Eureka in 1966 and 1967.[1]

Treatment	Plant height (cm)	Crown diameter long (cm)	Crown diameter short (cm)	Leaf length (cm)	Number of seedheads	Production (lbs./ac)
Commercial	45.1	10.9	8.1	17.8	6.4	586a[2]
Vinall	47.3	9.7	7.4	19.0	6.9	533b
6 #/ac	48.0	10.0	7.8	18.8	7.1	556a
9 #/ac	46.3	10.6	8.0	18.5	7.1	551a
12 #/ac	44.4	10.2	7.6	18.0	5.9	572a
Drilled	46.6	10.2	7.5	18.5	6.4	570a
Broadcast	45.8	10.4	8.0	18.4	7.0	549a
Fall 1966	47.1	10.9	8.2	18.8	7.5	592a
Spring 1967	45.3	9.6	7.4	18.0	5.9	526b
Overall						559

[1]For statistical analysis of this data, see Appendix, Table 32.

[2]A highly significant ($P<0.01$) difference occurs between two means not followed by the same letter.

Other vigor measurements taken in 1969 (Table 15) indicated that Vinall seed produced a taller plant with more seedheads, longer leaves, and smaller crown diameter than commercial seed. The 12-pound rate of seeding produced a shorter plant with fewer seedheads than the two lighter rates. Fall planting produced a taller plant with more seedheads.

Weed competition apparently had no effect on establishment and production of Russian wildrye. An analysis of variance showed that there were significantly more weeds in the fall than in the spring planting (Table 14). However, there were no significant differences in numbers of seedlings between spring and fall planting (Table 14). Production was significantly greater in fall than in spring. Average weed cover was 29 percent. There was a trend toward less weed cover with increased rate of seeding.

The 1969 weed cover data tend to support results of the establishment experiment (Table 14). Less weeds occurred in treatments where there were vigorous Russian wildrye plants. As rate of seeding increased, amount of weed cover decreased. Commercial seed, drilling, and fall planting all had less weed cover than counterpart treatments.

1969 Eureka seeding

Due to an extremely dry spring and light winter precipitation, almost no emergence of Russian wildrye seedlings was observed in the fall 1968-spring 1969 seeding, regardless of fertilizer treatment or rate of seeding.

Germination tests were run on seeds dug two months after spring planting and seven months after fall planting. Germination averaged 17.7 percent on fall planted seeds and 59.0 percent on spring planted seeds. There was little difference in germination between seeding rates (Table 16). Average number of viable seeds per foot of row was 9.3 from spring planting and 2.1 from fall planting. Over twice as many viable seeds occurred per foot of row in the two higher seeding rates than at the lightest rate from spring planting (Table 16). Part of the reduced seed viability may be due to damage from fungus (*Podosporiella verticillata*) infection. This fungus infected 8.2 percent of the seeds from the fall planting. Spring planted seeds were only 0.01 percent infected. Only slightly more cheatgrass seeds occurred per foot of row in fall planted (average = 2.4) than in spring planted seed (average = 2.0).

Table 16. Number of viable seeds per foot of row, percent germination, and number of cheatgrass seeds per foot of row in samples dug in summer 1969 from the Eureka Russian wildrye seeding made in fall 1968 and spring 1969.

Seeding rate	Viable seed/ ft. row		% germination		No Brte/ ft. row	
	Spring	Fall	Spring[1]	Fall	Spring	Fall
6 #/acre	5.3	2.9	55.3	22.8	1.5	1.3
12 #/acre	11.5	0.8	61.9	16.0	2.3	2.0
24 #/acre	11.2	2.6	59.8	4.2	2.3	3.9

[1]Statistical analysis of this data, see Appendix, Table 33.

Interspecific competition between Russian wildrye and four weeds in the field

The difficulty of maintaining the desired number of weeds per unit area encountered in the greenhouse was multiplied in the field. However, even though comparable densities of weeds could not be maintained, there were significant reductions in production and all vigor measurements taken under competition from any weed (Table 17).

Table 17. Vigor data on Russian wildrye field competition study conducted at Green Canyon in Cache Valley in 1968.[1]

Treatment	Plant height (cm)	No. leaves/ tiller	No. tillers/ plant	Leaf length (cm)	No. El.ju./ sq.ft.	Pounds air dry forage/	Pounds weeds/ plot
Control	13.9[a][2]	2.9[a]	21.8[a]	11.3[a]	1.0[a]	75[a]	0
Cheatgrass	5.5[c]	1.3[c]	2.4[b]	4.5[b]	0.5[a]	5[d]	16.8
Halogeton	10.4[ab]	2.4[ab]	9.5[b]	8.7[a]	0.9[a]	20[b]	4.4
Peppergrass	8.3[b]	2.0[b]	8.8[b]	7.2[a]	0.6[a]	14[c]	9.5
Russian thistle	5.5[c]	1.3[c]	1.3[b]	4.7[b]	0.4[a]	2[d]	85.3

[1]For statistical analysis of this data, see Appendix, Table 34.

[2]A significant ($P \angle 0.01$) difference occurs between two means not followed by the same letter.

Ground cover was essentially 100 percent in cheatgrass and Russian thistle plots, although number of plants per plot differed (Table 17). Ground cover in halogeton and peppergrass plots was similar. If species are grouped into those of high density (cheatgrass and Russian thistle) and those of low density (halogeton and peppergrass), comparisons between species can be made. No significant differences in production of Russian wildrye occurred between species of high density or between species of low density (Table 17). Competition from Russian thistle and cheatgrass caused similar reductions in vigor as did competition from halogeton and peppergrass.

Moisture depletion was more severe under cheatgrass and Russian thistle than under other species (Appendix Table 35). Cheatgrass and peppergrass depleted upper soil layers most. This is brought out particularly after the August 16 increase in moisture. After another rain prior to August 30, cheatgrass and peppergrass caused a decline in soil moisture, whereas all other stations showed an increase in moisture.

The plants that depleted soil moisture the most, i.e. Russian thistle and cheatgrass, shaded the soil the most. Therefore, any reduction in moisture loss by shading was overcome by their ability to extract soil moisture.

The last three readings at the 30-inch depth point out that Russian thistle depletes deep soil moisture. Readings at this depth in Russian thistle plots were below 50. Only in cheatgrass plots were other readings below 100.

Differences in soil temperatures were not apparent (Appendix, Table 36).

<u>Phenology and root growth</u>

During 1968 and 1969, rates of top growth were similar among all six species through the third and fourth leaf stage of Russian wildrye and crested wheatgrass (Table 18). During rapid growth, significant differences occurred in root and top growth (Appendix, Table 41). During 1968, rate of top growth ranked as follows: cheatgrass > crested wheatgrass > peppergrass > Russian wildrye > Russian

Table 18. Monthly top and root growth of six species grown in plastic tubes in the ground at Green Canyon in Cache Valley. Measurements are in centimeters.

Species	1968						1069					
	April	May	June	July	Aug.	Sept.	April	May	June	July	Aug.	Sept.
Russian wildrye												
plant height	3.0	3.2	10.2	12.1	12.7	12.4	3.1	4.4	9.7	17.6	24.1	Mature
root depth[1]		20.9	29.3	90.7	124.9	133.0		42.6	91.1	114.2	121.1	Mature
Crested wheatgrass												
plant height	2.1	5.9	11.4	26.7	27.2	26.1	1.0	9.0	22.7	Mature		
root depth		30.9	56.7	102.9	130.5	133.0		78.0	123.2	Mature		
Cheatgrass												
plant height	2.0	3.9	19.0	30.5	Mature		2.6	3.9	10.9	22.5	34.7	37.0
root depth		50.6	40.0	61.0	Mature			52.1	117.7	125.8	129.3	129.3
Halogeton												
plant height	0.4	1.1	2.1	13.9	25.7	27.6	2.9	4.9	8.0	12.8	17.2	17.8
root depth		34.0	59.0	136.3	133.0	133.0		25.7	64.5	87.2	122.8	127.4
Peppergrass												
plant height	1.1	4.0	9.0	24.0	Mature		1.0	2.5	9.5	17.6	26.1	27.6
root depth		22.0	115.7	137.5	Mature			37.7	106.6	125.8	128.0	122.4
Russian thistle												
plant height	1.8	2.9	3.5	19.1	25.9	26.8	2.8	4.8	7.8	10.6	12.4	12.2
root depth		56.6	74.5	129.8	133.0	133.0		27.0	55.4	81.0	118.1	125.8

[1]Roots were not visible in April either year.

thistle > halogeton (Table 18). During 1968, root growth ranked as follows: peppergrass > Russian thistle > cheatgrass > halogeton > crested wheatgrass > Russian wildrye. During 1969, rates of root and top growth ranked the same: peppergrass > Russian thistle > cheatgrass > halogeton > crested wheatgrass > Russian wildrye (Table 18). After July 1, rate of top growth of Russian wildrye decreased rapidly.

A comparison of the phenology of the six species (Appendix, Table 37) showed that all species except halogeton emerged earlier in 1968 due to a slightly earlier warming of the ground. Peppergrass and Russian thistle emerged several days before the other species in 1969. After mid April 1969, phenology of each species was similar to 1968.

Peppergrass was the first species to mature. It produced flower stalks as early as May 11 and was mature by late July each year.

Cheatgrass matured next. It produced flowering culms immediately after the fifth leaf stage, when above-ground tillering began. By mid August, it had the characteristic purplish color. It was fully mature by late August.

Russian wildrye did not produce seed and crested wheatgrass reached the hard dough stage by late August. Phenology of these two species appears similar (Appendix, Table 37) but Russian wildrye produced more top growth than crested wheatgrass (Appendix, Tables 41 and 42).

At about the third leaf stage, Russian wildrye began to tiller and produced more tillers than crested wheatgrass. When above-ground tillering began, secondary roots were visible in the tubes.

Russian thistle and halogeton were the last to mature. Russian thistle began to flower by late July and was mature by late September. Halogeton did not flower until late August or early September.

The area and extent of concentration of roots are shown in Table 19. Grass roots were concentrated in the upper 30 centimeters of the tubes. Roots of halogeton and peppergrass were concentrated in the upper 40 centimeters of the tubes. Russian thistle roots were distributed the length of the tubes (125 cm), but the main concentration was in the upper 60 centimeters.

Table 19. Area and extent of concentration of roots at the end of the 1968 growing season on grasses and forbs grown in plastic tubes at Green Canyon in Cache Valley.

	Area of maximum[1] concentration	% of tube covered by roots
Russian wildrye	29.0 cm	18
Crested wheatgrass	31.0	26
Cheatgrass	28.5	10
Halogeton	40.9	25
Peppergrass	41.0	25
Russian thistle	63.3	30

[1]Depth to which 50% or more of the roots were concentrated.

[2]Numbers represent percentage of surface of tube covered by roots in area of maximum root concentration.

At the end of the 1968 growing season ocular estimates were made of the percentage of the tube surface in the area of maximum root concentration covered by roots (Table 19). Russian thistle had the most extensive root system; halogeton and peppergrass followed in second place; crested wheatgrass in third place; Russian wildrye in fourth place; and cheatgrass had the least extensive root system of all six species.

Snowville Russian wildrye-crested wheatgrass clipping study

Effects of season and intensity of clipping on thick and thin stands of Russian wildrye and crested wheatgrass were studied in Curlew Valley west of Snowville, Utah. The study was initiated in 1964. Clipping was done in 1964, 1965, 1966, 1967, and 1968. Final data were taken in 1969.

Species and stand density differences. There were significant differences between species and densities within species (Appendix, Table 45).

Russian wildrye produced significantly more herbage than crested wheatgrass (Appendix Tables 44 and 45). Crown density ratings and crown diameter were significantly greater for Russian wildrye than for crested wheatgrass.

Thin stands of either species were more productive than thick stands (Appendix, Tables 44 and 45). During 1968, thick stands of Russian wildrye produced more than thick stands of crested wheatgrass. Crown density ratings and crown diameter were significantly greater in thin stands than in thick stands.

Crown density rating was the best measure of vigor. When all vigor measurements were used as dependent variables (x's) and production was used as the independent variable (y), 82 percent of the variability in production was accounted for. However, crown density rating alone accounted for 80 percent of the variability.

Season of herbage removal. To properly evaluate the effects of season of clipping on forage production, two factors must be considered: (1) amount of forage produced at clipping and (2) effect of herbage removal on plant vigor (Appendix, Table 43). Clipping both early and late produced the most forage for animal consumption (Appendix, Table 43). However, plants clipped twice the same year were least vigorous and produced less herbage on a yearly basis (Table 20). Late clipping was also detrimental to production. Least forage was available for animal consumption from early clipping (Appendix, Table 43), but this clipping also caused least damage to plant health.

Effects of season of clipping were most apparent in thick stands at the 1969 data collection (Appendix, Table 43). Crown density ratings were lowest in both species due to clipping early and late on the same plant. Plants were damaged least by early clipping. There was a decline in crown density rating from 1965 to 1969.

Table 20. Pounds of dry matter produced per acre in 1969 in Snowville study after five years of clipping.

Treatment	Species	
	Ag.cr.	El.ju.
Season		
Early clipped	202	573
Early & late clipped	163	359
Mid clipped	176	424
Late clipped	182	356
Intensity		
25% clipped	212	456
50% clipped	181	469
75% clipped	148	370
Density		
Thick stand	196	376
Thin stand	165	484

Crown diameters increased from 1965 to 1969 (Appendix, Table 43). The greatest increase in crown diameter occurred in plants clipped early, and the least increase occurred in plants clipped late.

Intensity of clipping. The heavier the intensity of clipping, the higher the amount of forage available for animal consumption (Appendix, Table 44). Plants clipped the heaviest were damaged most (Table 20). Crown density ratings and crown diameter measurements help emphasize this. There was a reduction in crown density and an increase in crown diameter, and changes were greatest on plants clipped most heavily (Appendix, Table 44).

Final vigor measurements. Final evaluation of this study was made in 1969 (Tables 20 and 21). These data emphasize the results already discussed. Russian wildrye produced significantly more herbage per plant than crested wheatgrass (Table 21). Thin stands produced more than thick stands.

On a per acre basis, Russian wildrye produced two to three times as much forage as crested wheatgrass after five years of clipping (Table 20).

The effects of species and intensity of clipping are apparent in selected photographs of treated plants (Figure 7).

Russian wildrye was more vigorous than crested wheatgrass under any treatment (Table 21). Average crown diameter for Russian wildrye was 34, and for crested wheatgrass it was 22. Average crown density rating for Russian wildrye was 5, and for crested wheatgrass it was 4. Plant height and leaf length for Russian wildrye were significantly greater than for crested wheatgrass.

Number of plants per 9.6 sq. ft. plot averaged: Russian wildrye, thick stand--5.5, thin stand--3; crested wheatgrass, thick stand--8, thin stand 6.

Effects of species and density of stand are clearly reflected in number of seedheads produced (Table 21). At both stand densities Russian wildrye produced more seedheads than crested wheatgrass. Both species produced more seedheads in thin stands than in thick stands, but the

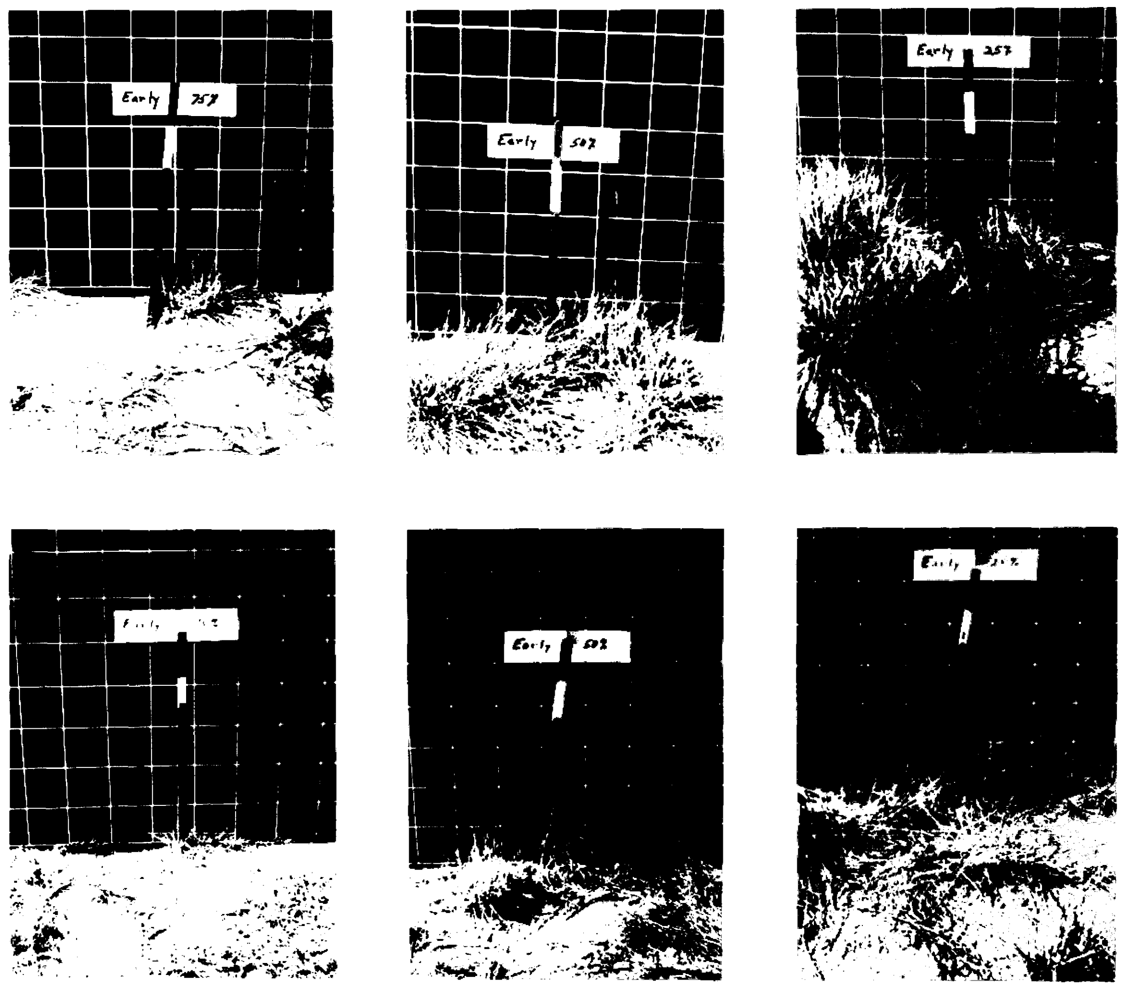

Figure 7. Russian wildrye (upper row) and crested wheatgrass (bottom row) after five years (1964-1968) of clipping at three intensities in Curlew Valley.

Table 21. Final vigor data taken during 1969 on Curlew Valley clipping study.

	Grams dry matter per plant				Crown diameter (cm)			
	Early	Early & late	Mid	Late	Early	Early & late	Mid	Late
Crested wheatgrass								
Thick stand								
clipped 25%	4	3	5	3	21	19	20	17
clipped 50%	3	3	3	4	19	16	16	19
clipped 75%	2	1	2	2	12	13	39	26
Thin stand								
clipped 25%	9	6	7	9	30	26	26	30
clipped 50%	7	4	4	7	28	27	24	27
clipped 75%	5	2	3	4	25	22	24	23
Russian wildrye								
Thick stand								
clipped 25%	11	8	10	9	32	30	32	
clipped 50%	7	5	11	9	28	28	30	32
clipped 75%	6	4	5	6	28	23	24	29
Thin stand								
clipped 25%	58	44	26	29	41	43	38	36
clipped 50%	69	37	40	26	47	43	45	38
clipped 75%	40	24	33	26	39	35	38	34

Table 21. Continued.

	Plant height (cm)				Leaf length (cm)			
	Early	Early & late	Mid	Late	Early	Early & late	Mid	Late
Crested wheatgrass								
Thick stand								
clipped 25%	17	18	17	15	9	14	16	9
clipped 50%	15	11	14	15	7	9	13	9
clipped 75%	10	10	12	13	5	8	9	8
Thin stand								
clipped 25%	20	21	17	19	9	16	16	9
clipped 50%	19	18	15	19	10	14	14	9
clipped 75%	16	17	14	14	9	12	13	7
Russian wildrye								
Thick stand								
clipped 25%	33	30	30	28	15	14	16	15
clipped 50%	20	26	24	28	14	11	15	15
clipped 75%	27	18	21	25	13	8	11	12
Thin stand								
clipped 25%	36	39	30	33	18	18	17	19
clipped 50%	38	35	35	33	19	17	21	16
clipped 75%	32	31	34	34	16	13	13	18

Table 21. Continued

	Crown density rating[1]				No. of seedheads				No. of plants/ 9.6 sq.ft. plot			
	Early	Early & late	mid	late	Early	Early & late	Mid	Late	Early	Early & late	Mid	Late
Crested wheatgrass												
Thick stand												
clipped 25%	6	4	5	4	4	1	1	0	8	7	8	9
clipped 50%	5	2	4	4	2	1	0	1	8	8	9	8
clipped 75%	4	1	4	2	1	2	1	1	9	7	9	8
Thin stand												
clipped 25%	7	6	6	4	6	4	2	2	5	6	6	6
clipped 50%	6	5	4	5	4	2	2	5	6	6	7	5
clipped 75%	5	3	4	3	8	5	4	5	6	6	6	6
Russian wildrye												
Thick stand												
clipped 25%	6	6	5	4	8	8	5	4	5	5	6	6
clipped 50%	6	4	5	4	5	6	8	6	5	6	6	5
clipped 75%	5	3	4	3	8	5	4	5	6	6	6	6
Thin stand												
clipped 25%	7	7	7	6	37	27	15	24	3	3	3	3
clipped 50%	7	7	7	5	45	29	28	17	3	3	3	3
clipped 75%	6	6	6	4	23	25	18	20	3	3	3	3

[1]Crown density rating--1 = 10% live material in crown, 2 = 20%, . . . 10 = 100%.

difference is most drastic from the thin to thick stands of Russian wildrye. Russian wildrye produced most seedheads in the thin stand when clipped early at 50 percent.

DISCUSSION

Effects of Competition

Effects of density. There was an inverse relationship between weed density and vigor of Russian wildrye. The effect of weed density is apparent from all competition studies. In both studies where large pots were used, production and vigor of Russian wildrye were reduced as weed density increased. Using the replacement series, increased weed density reduced production of Russian wildrye, but resulted in a taller, more elongated plant. Though data on the effect of weed density was limited, the same general relationships were apparent in the field.

Effects of species. Russian wildrye was a strong competitor with itself. Optimum production was obtained at a density of 37 plants per 6-inch pot. However, production per plant was optimum at one plant per pot and declined sharply with the slightest increase in density. The weeds were severe competitors with themselves as density increased. At 1, 25, and 50 plants per pot, per plant production on the weeds averaged 5, 0.2, and 0.1 grams, respectively.

The combination of three weeds caused greatest reductions in vigor of Russian wildrye. Combinations of two weeds caused more reduction in vigor than any single species. As a single species, Russian thistle caused greatest reduction in vigor of Russian wildrye, cheatgrass caused the next greatest reduction, and peppergrass caused least reduction in vigor.

Moisture use and competition. Russian wildrye was a poor competitor for moisture. It used more water to produce a gram of dry matter than crested wheatgrass or weeds. Crested wheatgrass was also an elaborate moisture user. Peppergrass was the poorest competitor of the weeds, and was the most elaborate user of water.

Cheatgrass and Russian thistle were the most severe competitors for moisture under field conditions. Cheatgrass depleted moisture in upper soil layers, and Russian thistle depleted deeper soil layers. Poor stands of halogeton and peppergrass prohibit conclusions concerning these two species.

Information gained on area and extent of root concentration indicates that Russian thistle would be the most severe competitor with either Russian wildrye or crested wheatgrass because its roots extensively occupy all layers of the soil. Cheatgrass did not develop an extensive root system in the tubes. Most of its roots were concentrated in upper soil layers where they would be in direct competition with Russian wildrye and crested wheatgrass roots.

There was no indication that Russian wildrye produced less roots or produced a secondary root system later than crested wheatgrass. Russian wildrye may have a slight advantage over crested wheatgrass in this characteristic. When Russian wildrye was rewatered late as plants were going dormant, it made an immediate response by producing more roots. This was not observed on crested wheatgrass.

Time of growth may offer answers to competitive ability. Peppergrass was never a strong competitor. It matures rapidly, sending down roots earlier and more rapidly than other species. Its short life cycle would allow it to compete with introduced species for only a short period. Cheatgrass matures rapidly, but it usually occurs in such dense stands that it is a severe competitor. Halogeton and Russian thistle are late-maturing species, halogeton maturing shortly after Russian thistle. These two species compete with grass seedlings after peppergrass and cheat-grass have matured. Often on native rangelands where grasses such as crested wheatgrass and Russian wildrye are introduced, there is competition from one or more of the early-maturing species, and subsequently competition from one or more of the late-maturing species.

<u>Nature of soil and competition</u>. The nature of the soil in which a plant is to be introduced may enhance or inhibit the plant's competitive ability. Factors such as texture, fertility, pH, salinity, compactness, crusting, are important. Soil texture may limit root growth and reduce the competitive ability of introduced species. Salinity and root growth habit of a plant may interact to give one species a competitive advantage. For example,

roots of Russian wildrye tend to grow most extensively in the surface foot of soil. This may explain why it grown better in saline soils than some wheatgrasses that do not concentrate roots at the surface--salts are partially leached out of surface soil, or are leached out for part of the year, giving Russian wildrye the advantage.

Eureka Seedings

Results of the 1967 seeding show that after three years more plants were established by using commercial than Vinall seed, and that more plants were established by the twelve-pound rate of seeding. Forage production was greatest using commercial seed and fall planting. At the last data collection there were no differences in drilling and broadcasting, but during the first and second years, drilling was significantly better than broadcasting.

Data from the 1969 seeding indicates that fall planting is best. Germination trials performed on seeds dug from fall and spring plantings indicate that germination is somewhat lower from fall planting. This is contrary to the 1967 seeding.

The 1967 study area was freshly plowed and had no known history of cheatgrass infestation. The 1969 study area was freshly plowed, but had been moderately infested with cheatgrass. Seeds dug in the 1969 seeding had a moderate infestation of a fungus, *Podosporiella verticillata*, of which cheatgrass is an intermediate host. Therefore, both moisture variations and fungus infestation could partly explain the lowered germination of fall-planted seed.

Snowville Clipping Study

Methods. A discussion of methods of data collection in this study is warranted because of the different personnel who collected data. Only crown diameter, crown density, and production were used to analyze the experiment.

Forage production was considered the best measure of plant response to the clipping treatments. However, only in 1969 was a final analysis made of the forage produced by each treatment. During previous years, only production at the time of clipping at the given intensity of clipping was taken for a given treatment. No final yearly production data were taken. For example, comparisons prior to 1969 had to be made on the basis of one plant clipped 25 percent in April, one in May, and one in June. Production was not taken at the end of the growing season.

Plant height had to be eliminated from all data prior to 1969. It had little meaning for the end of the growing season vigor measurement because height was confounded by both date and intensity of clipping. Since vigor measurements made prior to clipping were made in April, May, and June, it is not valid to compare growth of those plants clipped early to those clipped at the mid or late date.

Discussion. The thin stand of Russian wildrye performed extremely well under all seasons and intensities of clipping. Under the harsh conditions of the desert-like environment it out-performed crested wheatgrass. It produced more forage and maintained vigor better than did crested wheatgrass. Per acre production of Russian wildrye was 3 to 4 times that of crested wheatgrass under any intensity, season, or stand density. At the end of five years of clipping, the thin stand of Russian wildrye had at least 10 percent more live material per plant than the thin stand of crested wheatgrass. The thin stand of Russian wildrye produced 2 to 3 times more seedheads per unit area than crested wheatgrass.

Early and mid season clipping at light and moderate intensities were least detrimental to vigor of either species. Heavy clipping late in the season or combined early and late clipping was most detrimental to the plant. If recommendations were made from these data, most forage production with least damage would come from grazing Russian wildrye early or mid season at a moderate intensity.

SUMMARY

Russian wildrye is an introduced grass that shows promise for seeding foothill ranges in the Intermountain west. Much Russian wildrye research has been done in the northern Great Plains. Less work has been done in the Intermountain area. This research was designed to study establishment and survival of this species on foothill ranges in Utah.

Greenhouse studies were conducted at the Utah State University Campus. These studies conducted during 1967, 1968, and 1969 included (1) effects of competition on vigor and production of Russian wildrye, (2) moisture used by seedlings of Russian wildrye and four weeds, and (3) effects of moisture level and depth of planting on emergence and seedling vigor.

Field studies were conducted at three locations--Tintic, Curlew, and Cache Valleys. During 1967 and 1969 at Tintic Valley, experiments were initiated to study effects of (1) seasons, (2) methods, and (3) intensities of seeding Russian wildrye. In 1968 and 1969 studies were made of phenology and root growth of Russian wildrye, crested wheatgrass, and the four weeds near Green Canyon in Cache Valley. At this area in 1968, a field competition study between Russian wildrye and the four weeds was conducted. From 1964 through 1969 in Curlew Valley a study was conducted of the effects of seasons and intensities of clipping Russian wildrye and crested wheatgrass at two stand densities.

Results of the competition studies showed that there was an inverse relationship between weed density and Russian wildrye seedling vigor. Cheatgrass and Russian thistle were the most severe competitors with Russian wildrye. Halogeton was moderate and peppergrass was the weakest competitor of the weeds.

Results of the moisture use study show that Russian wildrye, crested wheatgrass, and peppergrass were the most elaborate moisture users, indicating that these three are poor competitors. Results of the phenology and root growth study indicate that Russian thistle had the most extensive root system, and therefore would be a severe competitor. Cheatgrass and peppergrass were early-maturing species, and Russian thistle and halogeton were late-maturing species. The most severe competition would come from a combination of an early-maturing species plus a late-maturing species.

At Tintic Valley, the best stand was obtained by drilling twelve pounds of seed per acre in the fall. Vinall seed was no better than commercial seed. Optimum planting depth for Russian wildrye was one-quarter inch. Seeding failures at Tintic Valley during two consecutive years were attributed to low precipitation, variations in temperature and moisture, and lowered germination due to fungus infestation of seed in the soil.

Under harsh temperature and moisture conditions in Curlew Valley, Russian wildrye out-performed crested wheatgrass under all seasons and intensities of clipping and at two stand densities. The highest production and most vigorous plants came from thin stand densities of Russian wildrye and crested wheatgrass. After five years of clipping, it was concluded that highest production with least reduction in vigor came from Russian wildrye clipped moderately in early or mid season.

From the results of this research, no definite recommendations can be made as to the suitability of Russian wildrye for seeding on foothill ranges. Many insights were gained into the seedling characteristics of the species, but further study should be made of Russian wildrye seedling morphology. However, where Russian wildrye can be successfully established, it is highly productive and persists better under grazing under drier conditions than crested wheatgrass.

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APPENDIX

Table 22. Analysis of variance of emergence and vigor data presented in Table 4.

Source	D.F.	Mean Squares				
		Plant Height	No. tillers per tiller	No. tillers per plant	Leaf length	% emergence
Replication	3	816.0**	11.3**	15.9**	411.5**	15.4*
Soil	1	3473.3**	28.9**	116.9**	1783.7**	1486.4**
Treatments	12	36.7	1.3	6.4**	37.7	5.4
Soil X Treat	12	16.9	0.8	3.3*	10.8	6.3
Error	75	28.9	1.1	1.1	22.9	4.4
Sampling	208	16.3	0.7	0.9	12.5	3.2

*Significance at the 0.05 level.

**Significance at the 0.01 level.

Table 23. Analysis of variance of vigor and production data presented in Table 5.

		Mean Squares				
Source	D.F	Plant Height	No. leaves per tiller	No. tillers per plant	Leaf length	Production
Replication	3	54.3	0.7	4.2	25.5	1.3
Treatments	12	62.1**	1.4**	14.8**	39.5*	2.6**
Error	36	20.3	0.4	1.6	18.7	0.6
Sampling	104	15.1	0.2	1.3	10.3	0.3

*Significance at 0.05 level.

**Significance at 0.01 level.

Table 24. Analysis of variance of vigor and production data presented in Table 6.

Source	D.F.	Mean Squares				
		Plant Height	Leaf Length	No. tillers per plant	No. leaves per tiller	Production
Replication	3	126.9**	100.6**	20.6**	18.8**	1.1**
Treatment	21	46.5**	31.0**	6.5**	1.2	3.3**
Error	63	13.1	7.7	0.8	1.0	0.2
Sampling	176	12.9	9.6	0.6	1.1	0.2

*Significance at 0.05 level.

**Significance at 0.01 level.

Table 25. Analysis of variance of data presented in Tables 7, 8, and 9.

Source	D.F.	Mean Squares Production
Replication	1	17.1**
Species (Sp)	4	246.1**
Densities (De)	2	69.1**
Sp X De	8	28.8**
Error	74	2.9

**Significance at 0.01 level.

Table 26. Analysis of variance of data presented in Table 10.

Source	D.F.	Mean Squares Production
Replication	1	0.98**
Species (Sp)	4	3.04**
Densities (De)	2	2.05**
Sp X De	8	0.17
Error	74	0.12

**Significance at 0.01 level.

Table 27. Analysis of variance of data presented in Table 11.

Source	D.F.	Mean Squares Grams H_2O Used
Replication	2	157
Dates (Da)	2	343,789**
Species (Sp)	5	27,335**
Da X Sp	10	13,286**
Error	142	1,142

**Significance at 0.01 level.

Table 28. Analysis of variance of data presented in Table 13.

Source	D.F.	Mean Squares: % emergences	Mean Squares: Plant height
% moisture	8	679.0**	214.9**
Error	81	5.3	0.7

**Significance at 0.01 level.

Table 29. Analysis of variance of data presented in Figure 6.

		Mean Squares
Source	D.F.	Emergence
Depth	6	528.0**
Error	63	4.1

**Significance at 0.01 level.

Table 30. Analysis of variance of data presented in Table 14.

Source	D.F.	Mean Squares: No. El. ju. per 0.96 sq. ft.	Mean Squares: No. weeds per 0.96 sq. ft.
Replication	2	7.3	13.2
Species (Sp)	1	65.4**	8.9
Rates (Ra)	2	53.2**	3.2
Methods (Me)	1	37.8**	0.2
Seasons (Se)	1	14.2	37.4**
Sp X Ra	2	10.1	9.4
Sp X Me	1	7.8	11.3
Sp X Se	1	1.2	5.0
Ra X Me	2	5.3	9.0
Ra X Se	2	1.5	1.6
Me X Se	1	5.5	42.1**
Sp X Ra X Me	2	4.8	2.6
Sp X Ra X Se	2	0.3	2.1
Sp X Me X Se	1	2.2	3.2
Ra X Me X Se	2	2.4	6.6
Sp X Ra X Me X Se	2	2.5	17.8
Error	46	4.9	6.5
Sampling	648	3.4	3.0

**Significance at 0.01 level

Table 31. Analysis of variance of Russian wildrye vigor data collected at Tintic Valley on seeding made in 1967.

Source	D.F.	Mean Squares: Plant height	Leaves per tiller	Tillers per plant	Leaf length	No.plants/	Production
Replication	2	57.9	20.0	2,923.8*	47.0	886.4*	22,521.9**
Species (Sp)	1	49.6	8.2	2,358.1	47.0	2,741.7**	21,806.4**
Rates (Ra)	2	45.8	7.4	106.6	70.4	2,437.5**	5,172.9
Methods (Me)	1	30.8	0.4	49.6	2.7	1,878.6**	7,941.4*
Seasons (Se)	1	165.3	13.9	7,559.6**	156.8	183.0	17,537.0**
Samples (Sa)	1	191.2	3.9	63,826.2**	131.8	977.7*	10,629.1*
Sp X Ra	2	262.9	0.7	26.9	79.7	35.2	752.3
Sp X Me	1	169.2	1.3	144.9	39.2	4.2	6,347.5
Sp X Se	1	122.5	0.3	632.8	64.8	58.4	1,054.2
Sp X Ra X Me	2	88.9	0.1	883.1	24.4	49.5	1,451.4
Sp X Ra X Se	2	9.8	6.7	11,664.6	10.0	50.0	1,936.6
Sp X Me X Se	1	0.2	2.6	30.8	1.4	11.0	1,397.2
Ra X Me X Se	2	138.0	6.5	384.4	56.5	944.5*	1,890.3
Ra X Me	2	83.7	0.9	1,692.8	18.2	134.8	43.0
Ra X Se	2	99.7	2.2	1,998.6	44.0	517.8	3,242.9
Me X Se	1	10.5	0.2	36.9	1.1	415.6	1,578.3
Sp X Ra X Me X Se	2	15.0	2.0	86.4	22.2	22.3	718.6
Error	117	431.4	18.0	886.1	247.5	199.5	1,755.2
Sampling	576	48.1	1.4	444.1	28.9	46.7	433.7

*Significance at 0.05 level.

**Significance at 0.01 level.

Table 32. Analysis of variance of production of data presented in Table 15.

Source	D.F.	Mean Squares Production
Replication	2	357,411.8*
Species (Sp)	1	1,029,201.0**
Rates (Ra	2	56,986.8
Methods (Me)	1	168,099.9
Seasons (Se)	1	1,566,352.0**
Sp X Ra	2	81,375.4
Sp X Me	1	471,975.6*
Sp X Se	1	147,424.1
Ra X Me	2	358,901.4*
Ra X Se	2	1,318,565.0**
Me X Se	1	916,232.5**
Sp X Ra X Me	2	2,650.4
Sp X Ra X Se	2	793,746.1**
Sp X Me X Se	1	149,744.2
Ra X Me X Se	2	123,468.0
Sp X Ra X Me X Se	2	224,407.4
Error	1414	86,030.3

*Significance at 0.05 level.

**Significance at 0.01 level.

Table 33. Analysis of variance of data presented in Table 16.

Source	D.F.	Mean Squares % Germination
Replication	2	616.5
Seeding rate	2	1,266.0*
Error	130	322.2

*Significance at 0.05 level.

Table 34. Analysis of variance of data presented in Table 17.

Source	D.F.	Mean Squares					
		Plant height	No. leaves per tiller	No. tillers per plant	Leaf length	No. plants/ 9.6 sq.ft.	Production
Replication	3	52.6	6.2	1,488.8	55.4	7.3	170.0
Species	5	848.0**	38.5**	4,702.4**	556.6*	51.8*	640.5*
Error	15	84.4	3.3	512.8	74.2	6.6	107.9
Sampling	456	42.8	2.0	104.3	31.2	3.4	14.0

*Significance at 0.05 level.

**Significance at 0.01 level.

Table 35. Moisture block readings at four depths under four species of grasses and forbs grown in competition with Russian wildrye at Green Canyon in Cache Valley in 1968.[1]

Species	Depth inches	4/21	4/28	5/6	5/16	7/5	7/25	8/16	8/30	10/4
Cheatgrass	3	172	174	88	166	0	0	83	62	0
	9	176	171	174	136	3	0	0	160	1
	18	174	175	178	174	52	3	4	16	7
	30	165	164	166	166	163	144	112	108	90
Peppergrass	3	168	174	131	174	1	0	142	98	0
	9	174	174	174	160	18	4	5	170	4
	18	176	176	179	178	122	87	90	144	62
	30	174	170	177	178	182	181	180	182	150
Russian thistle	3	176	182	166	166	1	0	22	64	0
	9	176	179	169	169	18	2	0	140	2
	18	176	179	178	178	52	4	2	15	2
	30	166	172	175	175	178	136	41	50	36
Russian wildrye (control)	3	155	150	74	171	5	1	90	130	10
	9	175	178	171	137	135	134	120	185	52
	18	170	172	174	169	174	170	160	180	145
	30	169	171	172	171	175	175	175	178	165
Halogeton	3	180	173	181	180	26	0	126	137	0
	9	175	178	180	177	70	22	2	165	2
	18	174	175	179	178	162	140	56	134	46
	30	175	176	178	180	185	185	182	185	173

[1]Figure represents averages of two stations in ohms resistance.

Table 36. Temperature in degrees centigrade at four depths under four species of grasses and forbs grown in competition with Russian wildrye at Green Canyon in Cache Valley in 1968.

Species	Depth inches	3/30	4/21	4/28	5/6	5/16	7/5	7/25
Cheatgrass	3	6.5	7.5	14.0	13.0	7.5	28.5	33.5
	9	5.5	4.5	6.5	10.5	7.0	23.5	25.0
	18	4.3	4.3	5.5	9.5	8.8	19.0	22.0
	30	2.5	4.5	4.0	8.0	9.0	16.5	19.0
Peppergrass	3	7.5	7.8	15.8	11.3	8.0	29.5	34.0
	9	6.0	5.5	7.0	11.5	8.0	25.0	25.0
	18	3.3	4.5	6.5	10.8	9.5	19.8	22.0
	30	3.5	4.5	5.5	8.0	9.5	16.5	19.0
Russian thistle	3	6.3	6.8	14.5	12.5	6.8	28.0	33.0
	9	5.8	4.5	8.0	11.5	7.9	24.0	25.0
	18	4.8	3.8	6.3	10.8	8.0	19.3	22.0
	30	2.5	4.0	5.0	7.8	8.3	15.5	19.0
Russian wildrye	3	5.5	7.0	13.0	12.5	6.5	29.5	33.0
	9	6.0	5.5	7.5	11.0	8.0	25.5	25.0
	18	4.0	3.5	5.0	9.5	8.5	20.0	22.0
	30	3.0	4.5	5.0	9.0	9.0	16.5	19.0
Halogeton	3	5.5	7.0	14.0	12.0	7.5	28.5	33.0
	9	4.5	5.5	8.0	11.0	8.0	25.0	25.0
	18	2.5	4.5	5.0	9.5	8.0	19.0	22.0
	30	1.5	4.5	5.5	8.0	9.0	16.5	19.0

Table 37. Phenology of six species of grasses and weeds grown in tubes at Green Canyon in Cache Valley during 1968 and 1969.

Date	Species					
	Russian wildrye	Crested wheatgrass	Cheatgrass	Halogeton	Peppergrass	Russian thistle
3/16/68	emergence	emergence	emergence	-----	emergence	emergence
4/8/69	-----	-----	-----	-----	emergence	emergence
4/17/69	emergence	emergence	emergence	emergence	-----	-----
4/21/68	1-leaf	2-leaf	2-leaf	2-leaf	3-leaf	2-leaf
4/25	1-leaf	1-leaf	1-2 leaf	2-leaf	8-leaf	3-leaf
5/10/60	3-leaf	3-leaf	3-leaf	5-leaf	flower head	4-5 leaf
5/11/68	3-leaf	3-leaf	4-leaf	4-leaf	flower head	5-6 leaf
5/23/69	3-leaf	3-leaf	5-leaf	10-20 leaf	anthesis	8-10 leaf
5/25/68	4-leaf	4-leaf	early boot	10-20 leaf	anthesis	10-20 leaf
6/10/68	4-leaf	4-leaf	boot	10-20 leaf	soft dough	10-20 leaf
6/13/69	3-leaf	3-leaf	boot	40-50 leaf	soft dough	20-30 leaf
7/5/68	4-leaf	boot	milk	10-20 leaf	hard dough	10-20 leaf
7/9/69	4-leaf	4-leaf	anthesis	leaf	hard dough	10-20 leaf
7/21/69	4-leaf	boot	boot	leaf	seed shatter	flowers
7/25/68	4-leaf	anthesis	soft dough	leaf	seed shatter	leaf
8/21/69	5-leaf	5-leaf	hard dough	leaf	-----	milk
8/28/69	5-leaf	5-leaf	mature	leaf	-----	soft dough
8/30/68	6-leaf	hard dough	seed shatter	anthesis	-----	anthesis
9/12/69	6-leaf	5-leaf	seed shatter	anthesis	-----	dough
9/15/69	6-leaf	5-leaf	-----	dough	-----	mature

Table 38. Temperatures in degrees centigrade in phenology and root study tubes during 1969.

Date	Depth (in.)	Control	Tube
4/8	6	3.0	4.3
	24	5.5	5.5
4/17	6	4.5	7.3
	24	7.5	6.4
4/26	6	9.5	9.5
	24	8.0	7.5
5/11	6	11.0	12.5
	24	13.5	11.3
5/29	6	15.0	19.5
	24	16.5	16.3
6/13	6	14.5	16.2
	24	15.5	16.1
6/22	6	15.5	17.9
	24	15.0	16.3
7/1	6	14.5	16.6
	24	14.5	15.0
7/9	6	22.0	23.4
	24	16.0	16.8
7/21	6	19.0	22.3
	24	19.0	20.0
7/30	6	25.0	29.7
	24	19.0	20.2
8/7	6	19.0	22.8
	24	18.0	20.1
8/14	6	16.5	18.3
	24	18.5	20.5
8/21	6	19.0	22.4
	24	19.5	21.1
8/28	6	18.5	20.1
	24	19.5	21.0
9/5	6	19.0	18.9
	24	14.5	19.3

Table 39. Average moisture block readings in ohms resistance in phenology and root study tubes during 1969.

Date	Depth (inches)			
	3	9	18	30
4/8	173.0	175.5	175.0	179.0
4/17	175.0	175.5	174.5	177.0
4/26	180.0	180.0	178.0	180.0
5/11	180.0	180.0	180.0	180.0
5/29	125.4	177.1	182.6	182.9
6/13	127.3	174.9	181.9	182.4
6/22	179.6	182.1	183.4	183.9
7/1	177.6	181.4	181.8	182.1
7/9	134.4	179.5	182.8	183.3
7/21	77.3	137.0	181.6	183.4
7/30	62.9	130.8	171.4	183.5
8/7	149.1	175.8	175.4	183.1
8/21	92.8	166.0	170.0	182.0
8/28	30.1	98.9	112.9	144.9
9/5	14.4	47.6	78.7	120.0
10/24	147.3	13.0	22.0	69.0

Table 40. Analysis of variance of phenology data presented in Table 18 at one date in June.

Source	D.F.	Mean Squares	
		Plant height	Root depth
Years (Ye)	1	40.7**	5,188**
Species (Sp)	5	55.3**	4,229**
Ye X Sp	5	0.2	696
Error	108	0.5	286

**Significance at 0.01 level.

Table 41. Rate of top and root growth of six species of grasses and forbs grown in plastic tubes during 1968.

Species	Plant height (cm)	No. leaves	No. tillers	Leaf length	Root depth (cm)
3/16/68					
Russian thistle	0.4				NV[a]
Halogeton	0.2				NV
Russian wildrye	0.3				NV
Peppergrass	0.5				NV
Crested wheatgrass	0.4				NV
Cheatgrass	0.6				NV
4/21/68					
Russian thistle	1.7	2.2			NV
Halogeton	0.3	2.0			NV
Russian wildrye	2.8	1.1			NV
Peppergrass	1.6	2.6			NV
Crested wheatgrass	2.3	2.0			NV
Cheatgrass	2.1	2.0			NV
4/28/68					
Russian thistle	1.8	2.4	1.0		17.7
Halogeton	0.4	2.0	1.0		8.0
Russian wildrye	3.2	1.9	1.0	3.2	15.4
Peppergrass	0.6	3.3	1.0	0.7	23.8
Crested wheatgrass	1.8	1.8	1.0	2.1	13.3
Cheatgrass	2.0	3.9	1.0	2.0	25.8
5/11/68					
Russian thistle	2.1	5.5	1.0	1.5	43.1
Halogeton	0.9	4.0	1.0	0.6	26.1
Russian wildrye	2.6	2.6	1.0	2.6	20.6
Peppergrass	3.2	2.8	1.0	2.9	20.1
Crested wheatgrass	3.8	4.5	1.2	2.3	30.3
Cheatgrass	1.7	6.4	1.0	1.9	38.3
5/25/68					
Russian thistle	3.6	9.0	1.0	2.5	70.1
Halogeton	1.3	7.3	1.0	0.8	41.8
Russian wildrye	3.7	3.5	1.0	3.2	21.1
Peppergrass	4.7	3.5	1.1	4.1	23.9
Crested wheatgrass	8.0	4.0	1.4	3.2	31.5
Cheatgrass	6.1	8.5	1.0	2.9	62.8

[a]NV = Not visible

Table 41. Continued.

Species	Plant height (cm)	No. leaves	No. tillers	Leaf length	Root depth (cm)
6/10/68					
Russian thistle	3.5	12.5	1.0	2.8	74.5
Halogeton	2.1	10.0	1.5	1.0	59.0
Russian wildrye	10.2	4.0	3.3	7.0	29.3
Peppergrass	9.0	18.7	1.0		115.7
Crested wheatgrass	11.4	4.2	3.0	6.4	56.7
Cheatgrass	19.0	4.0	4.0	3.0	40.0
7/5/68					
Russian thistle	17.8	11.4	7.4	2.2	126.6
Halogeton	10.5	11.8	4.5	1.0	139.5
Russian wildrye	12.5	3.8	5.3	9.1	67.1
Peppergrass	24.0	7.4	3.3		137.5
Crested wheatgrass	28.9	5.0	4.6	7.3	87.2
Cheatgrass	30.5	4.0	6.2		61.0
7/25/68					
Russian thistle	20.3	9.1	9.1	2.3	133.0
Halogeton	17.3	16.2	4.7	1.9	133.0
Russian wildrye	11.7	4.0	5.6	9.2	114.3
Peppergrass	24.0	7.4	3.3		137.5
Crested wheatgrass	24.4	5.8	5.8	6.8	118.5
Cheatgrass	30.5	4.0	6.2		61.0
8/16/68					
Russian thistle	25.0	10.9	11.1	2.3	133.0
Halogeton	24.9	25.0	5.1	1.0	133.0
Russian wildrye	12.0	6.3	11.6	8.7	116.8
Peppergrass		MATURE			
Crested wheatgrass	27.2	6.6	10.2	6.1	128.0
Cheatgrass		MATURE			
8/30/68					
Russian thistle	26.8	11.0	11.0	2.0	133.0
Halogeton	26.4	25.0	5.0	1.0	133.0
Russian wildrye	13.4	4.2	12.8	13.7	133.0
Peppergrass		MATURE			
Crested wheatgrass	27.2	6.0	14.4	6.5	133.0
Cheatgrass		MATURE			
9/27/68					
Russian thistle	26.8	13.8	10.7	1.9	133.0
Halogeton	27.6	26.4	5.0	1.0	133.0
Russian wildrye	12.4	3.6	16.3	9.8	133.0
Peppergrass		MATURE			
Crested wheatgrass	26.1	4.9	15.3	7.7	133.0
Cheatgrass		MATURE			

Table 42. Rate of top and root growth of six species of grasses and forbs grown in plastic tubes during 1969.

Species	Plant height (cm)	No. leaves	No. tillers	Leaf length (cm)	Root depth (cm)	No. root tillers
4/17/69						
Russian thistle	1.7	1.0	1.0	1.1	NV[a]	0
Halogeton	1.8	1.0	1.0	1.3	NV	0
Russian wildrye	2.8	1.0	1.0	2.3	NV	0
Peppergrass	0.9	2.0	1.0	0.5	NV	0
Crested wheatgrass	0.9	5.2	1.0	1.3	NV	0
Cheatgrass	2.4	2.0	1.0	1.1	NV	0
4/25/69						
Russian thistle	3.8	1.1	1.0	3.3	NV	0
Halogeton	3.9	.9	1.0	3.4	NV	0
Russian wildrye	3.4	1.5	1.0	4.0	NV	0
Peppergrass	1.1	1.9	1.0	1.0	NV	0
Crested wheatgrass	1.0	7.8	1.0	2.3	29.7	0
Cheatgrass	2.7	2.7	1.0	1.9	NV	0
5/1/69						
Russian thistle	3.9	1.8	1.0	3.0	11.4	1.0
Halogeton	4.0	1.9	1.0	3.1	9.4	1.0
Russian wildrye	3.5	2.1	1.0	2.9	15.2	1.0
Peppergrass	1.1	2.0	1.0	1.0	14.0	1.0
Crested wheatgrass	1.3	8.0	1.0	2.1	53.8	1.0
Cheatgrass	2.7	4.0	1.0	1.6	21.1	1.0
8/28/69						
Russian thistle	12.8	4.1	14.4	13.8	125.8	2.7
Halogeton	18.0	4.3	12.9	9.0	127.4	2.9
Russian wildrye	26.2	4.1	20.3	9.7	122.4	2.5
Peppergrass	26.8	202.0	1.0	1.0	128.0	2.6
Crested wheatgrass			MATURE			
Cheatgrass	37.1	325.0	1.0	1.4	129.3	3.1
9/5/69						
Russian thistle	13.1	4.1	14.4	8.4	125.8	2.9
Halogeton	18.1	4.4	12.8	8.5	127.4	3.2
Russian wildrye			MATURE			
Peppergrass	27.9	189.0	1.0	1.0	122.4	2.3
Crested wheatgrass			MATURE			
Cheatgrass	37.2	338.0	1.0	1.5	129.3	2.1

[a]NV = Not visible

Table 42. Continued.

Species	Plant height (cm	No. leaves	No. tillers	Leaf length (cm)	Root depth (cm)	No. root tillers
9/11/69						
Russian thistle	11.5	4.0	14.2	7.7	125.8	3.0
Halogeton	18.0	4.5	11.9	7.9	127.4	3.1
Russian wildrye			MATURE			
Peppergrass	27.3	177.0	1.0	1.0	122.4	2.0
Crested wheatgrass			MATURE			
Cheatgrass	36.8	345.5	1.0	1.0	129.3	2.1
9/25/69						
Russian thistle	12.0	4.0	16.4	9.0	125.8	3.0
Halogeton	17.4	4.0	14.4	8.0	127.4	3.0
Russian wildrye			MATURE			
Peppergrass	27.7	209.0	1.0	1.0	122.4	2.0
Crested wheatgrass			MATURE			
Cheatgrass	37.1	37.6	1.0	1.0	129.3	2.0

Table 43. Effect of season of clipping on production per plant, crown density, and crown diameter on thick and thin stands of crested wheatgrass and Russian wildrye at three dates of clipping each year during five years of study at Snowville.[1]

	1965				1966			
	Ag.cr.		El.ju.		Ag.cr.		El.ju.	
	Thick	Thin	Thick	Thin	Thick	Thin	Thick	Thin
Production (grams)								
Early	3.8	6.7	6.2	12.9	1.7	7.5	7.0	21.8
Early & late	5.5	12.7	10.4	31.2	4.0	13.7	10.3	43.9
Mid	5.9	12.1	10.2	29.6	3.5	11.9	12.7	33.0
Late	4.5	13.1	9.1	22.1	3.2	8.3	9.5	32.6
Crown density rating[2]								
Early	6	8	8	9	6	8	8	9
Early & late	6	8	8	10	6	8	7	8
Mid	7	8	8	10	7	8	8	8
Late	7	8	8	10	7	8	8	8
Crown diameter (cm)								
Early	15	19	20	22	15	23	22	27
Early & late	16	19	21	23	16	22	22	29
Mid	16	19	21	22	17	23	23	29
Late	17	18	21	22	17	23	26	29

[1]For statistical analysis of these data, ee Appendix, Table 45.

[2]Crown density rating--1 = 10% live material in crown, 2 = 20% . . . 10 = 100%.

Table 43. Continued.

	1967				1968			
	Ag.cr.		El.ju.		Ag.cr.		El.ju.	
	Thick	Thin	Thick	Thin	Thick	Thin	Thick	Thin
Production (grams)								
Early	1.5	6.1	4.0	14.8	1.0	4.6	5.2	19.8
Early & late	4.2	16.8	7.8	34.1	3.5	7.1	6.6	24.8
Mid	4.4	6.8	6.3	17.4	2.4	5.6	8.4	25.1
Late	5.5	19.9	11.2	26.5	4.7	10.5	8.1	15.1
Crown density rating								
Early	4	7	7	8	4	7	5	8
Early & late	4	6	5	8	3	5	8	3
Mid	5	7	7	8	5	5	7	7
Late	5	7	7	8	5	6	6	7
Crown diameter (cm)								
Early	16	24	25	29	17	26	30	35
Early & late	17	22	24	29	19	23	24	32
Mid	18	22	24	31	23	25	30	37
Late	19	25	26	31	18	23	27	31

Table 43. Continued.

	1969			
	Ag.cr.		El.ju.	
	Thick	Thin	Thick	Thin
Production (grams)				
Early	DATA[1] NOT COMPARABLE			
Early & late				
Mid				
Late				
Crown density rating				
Early	5	6	6	7
Early & late	5	5	4	7
Mid	4	5	5	7
Late	3	4	4	5
Crown diameter (cm)				
Early	17	28	29	42
Early & late	16	25	27	39
Mid	19	25	28	40
Late	19	27	31	36

[1]Data not comparable because no clipping was done in 1969.

Table 44. Effect of clipping intensity on production per plant, crown density, and crown diameter on thick and thin stands of crested wheatgrass and Russian wildrye during five years of study at Snowville.[1]

	1965				1966			
	Ag.cr.		El.ju.		Ag.cr.		El.ju.	
	Thick	Thin	Thick	Thin	Thick	Thin	Thick	Thin
Production (grams)								
25%	3.4	7.7	5.5	14.5	2.1	8.7	7.1	23.2
50%	4.4	10.4	9.2	25.9	3.6	10.2	10.4	37.2
75%	7.0	15.4	12.2	31.5	3.6	12.2	12.2	38.1
Crown density rating[2]								
25%	7	8	8	10	7	8	8	9
50%	7	8	8	10	7	8	8	9
75%	6	8	7	10	6	7	7	8
Crown diameter (cm)								
25%	16	19	21	21	16	23	24	27
50%	16	19	21	23	16	23	23	29
75%	16	18	21	23	16	22	23	29

[1] For statistical analysis of these data, see Appendix, Table 45.

[2] Crown density rating--1 = 10% live material in crown, 2 = 20% . . . 10 = 100%.

Table 44. Continued

	1967				1968			
	Ag.cr.		El.ju.		Ag.cr.		El.ju.	
	Thick	Thin	Thick	Thin	Thick	Thin	Thick	Thin
Production (grams)								
25%	3.4	10.9	6.1	15.6	2.7	6.6	6.8	15.1
50%	4.1	14.5	7.5	25.1	3.2	8.1	7.3	24.5
75%	4.1	11.8	8.4	28.9	2.8	6.1	7.1	24.6
Crown density rating								
25%	6	7	7	8	6	7	6	8
50%	5	7	7	8	5	6	6	7
75%	3	6	6	7	3	5	4	6
Crown diameter (cm)								
25%	18	24	25	29	21	26	29	33
50%	18	24	25	31	20	24	28	35
75%	17	21	24	30	17	22	26	33

Table 44. Continued.

	1969			
	Ag.cr.		El.ju.	
	Thick	Thin	Thick	Thin
Production (grams)				
25%	DATA[1]			
50%	NOT			
75%	COMPARABLE			
Crown density rating				
25%	4	6	5	7
50%	4	5	5	7
75%	3	4	4	6
Crown diameter (cm)				
25%	19	28	31	39
50%	18	27	29	43
75%	16	23	26	36

[1]Not comparable because no clipping was done in 1969.

Table 45. Analysis of variance of data presented in Tables 43 and 44.

Source	D.F.	Mean Squares 1965 Crown Diameter	1965 Crown Density	1965 Production	1966 Crown Diameter	1966 Crown Density	1966 Production
Replication	3	3,172.7**	57.6**	2,398.9**	4,623.0**	2.9	5,683.3**
Species (Sp)	1	4,154.2**	614.4**	17,050.5**	10,107.9**	152.8**	51,439.1**
Densities (De)	1	849.4**	640.3**	27,053.4**	7,621.9**	307.1**	54,879.6**
Seasons (Se)	3	30.0	35.7**	2,834.8**	157.9	22.7**	3,038.1**
Intensities (In)	2	15.9	33.5*	6,165.0**	40.4	115.5**	3,518.5**
Sp X De	1	67.7	4.0	4,629.7**	137.3	5.9	14,783.1**
Sp X Se	3	5.8	5.2	723.3	27.0	1.9	132.7
Sp X In	2	28.7	8.7	945.2*	13.0	2.3	1,443.4
De X Se	3	49.7	13.5	1,002.6*	28.6	17.6**	1,363.8
De X In	2	1.3	24.3	1,086.9*	24.1	6.6	846.1
Se X In	6	10.6	15.4	341.4	38.0	1.9	283.3
Sp X De X Se	3	8.5	14.7	430.7	75.8	0.5	658.0
Sp X De X In	2	50.9	2.6	243.7	98.2	0.7	610.7
	6	21.2	3.6	57.5	16.3	1.5	158.4
	6	7.8	12.9	104.3	21.0	1.7	79.0
Sp X De X Se X In	6	12.8	6.1	76.5	10.7	0.7	114.0
Error	144	111.6	8.9	264.9	151.0	3.6	529.6
Sampling	768	16.8	5.4	85.4	31.6	2.1	120.4

*Significance at 0.05 level.

**Significance at 0.01 level.

Table 45. Continued.

Source	D.F.	Mean Squares: 1967 Crown Diameter	1967 Crown Density	1967 Production	1968 Crown Diameter	1968 Crown Density	1968 Production
Replication	3	3,059.4**	5.5	2,691.3**	4,662.5**	35.6**	2,068.1**
Species (Sp)	1	11,669.2**	714.2**	12,248.7**	18,850.5**	222.3**	20,773.4**
Densities (De)	1	7,232.5**	781.2**	35,608.2**	7,304.1**	552.1**	20,345.8**
Seasons (Se)	3	199.5	70.4**	5,426.1**	949.0**	116.4**	459.5
Intensities (In)	2	188.5	190.7**	1,788.2**	667.1*	418.8**	792.1
Sp X De	1	1.6	9.6	3,230.7**	66.2	5.4	6,405.1
Sp X Se	3	14.8	3.0	300.5	138.8	5.0	850.8
Sp X In	2	67.3	14.4*	993.9*	97.4	7.1	574.6
De X Se	3	14.7	6.3	2,185.6**	61.9	59.2**	264.6
De X In	2	27.9	11.1	833.7*	34.9	10.7	576.2
Se X In	6	27.4	3.4	146.9	44.3	5.8	104.4
Sp X De X Se	3	146.6	4.0	433.7	267.8	1.1	613.5
Sp X De X In	2	110.7	0.9	580.5	149.9	0.3	540.5
	6	9.8	2.7	232.3	54.9	4.1	163.1
	6	16.0	1.8	17.8	17.0	0.5	98.5
Sp X De X Se X In	6	36.0	1.4	95.7	59.4	1.9	88.9
Error	144	115.4	4.0	270.9	192.6	8.2	239.4
Sampling	768	29.6	2.1	96.8	44.4	3.4	75.9

*Significance at 0.05 level.

**Significance at 0.01 level.

Table 45. Continued.

Source	D.F.	Mean Squares 1969 Crown Diameter	Crown Density	Production
Replication	3	7,568.1**	24.3**	
Species (Sp)	1	37,001.7**	349.2**	
Densities (De)	1	21,375.9**	526.6**	
Seasons (Se)	3	200.7	156.2**	
Intensities (In)	2	1,383.7**	182.0**	
Sp X De	1	275.2	12.4	
Sp X Se	3	56.6	18.7**	
Sp X In	2	211.5	6.6	
De X Se	3	314.6	23.9**	
De X In	2	224.6	1.0	
Se X In	6	57.9	6.5	
Sp X De X Se	3	216.8	9.5	
Sp X De X In	2	216.7	0.2	
	6	76.5	5.1	
	6	62.7	1.5	
Sp X De X Se X In	6	67.2	4.5	
Error	144	262.2	5.2	
Sampling	768	52.2	3.0	

**Significance at 0.01 level.

VITA

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Doctor of Philosophy

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